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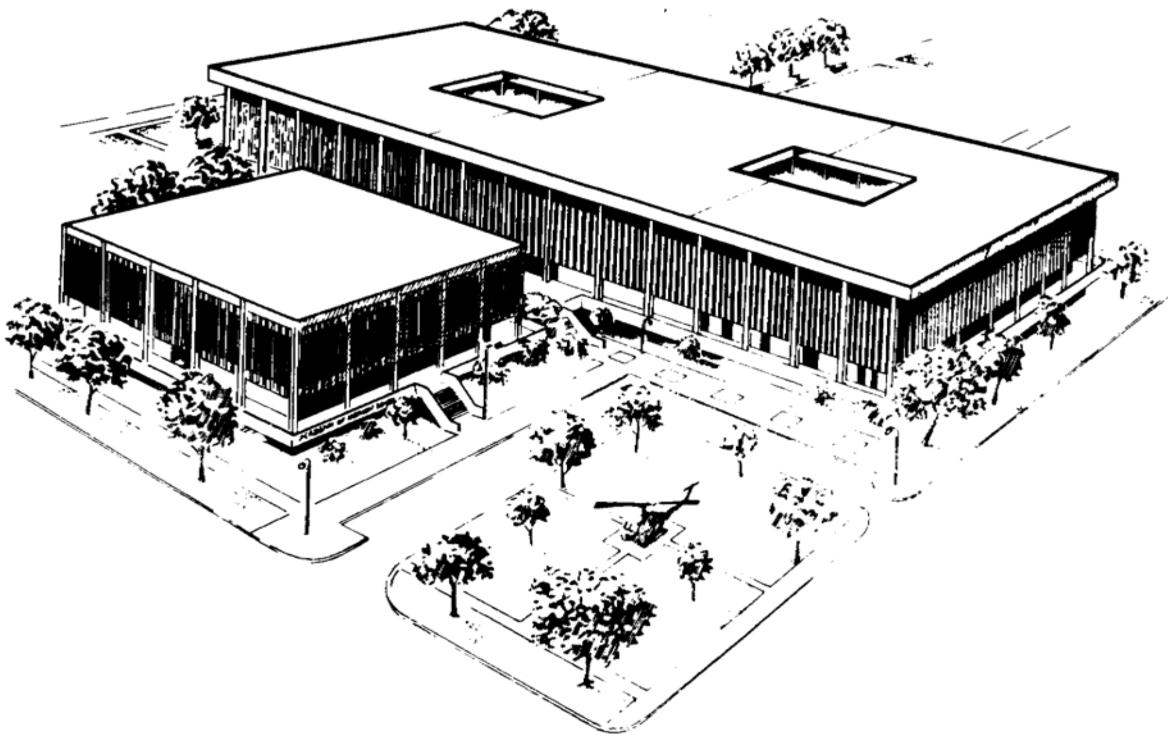

# PRESERVATION OF FOODS

SUBCOURSE MD0703 EDITION 100

## DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy of Health Sciences and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

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## CLARIFICATION OF TRAINING LITERATURE TERMINOLOGY

When used in this publication, words such as "he," "him," "his," and "men" are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

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## U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

## SUBCOURSE MD0703

## PRESERVATION OF FOODS

## INTRODUCTION

How do bacteria reproduce? Does the bacterial cell contain a nucleus? What are the shapes of bacteria? If you cannot answer these questions now, you should be able to when you have completed this subcourse, and you should also know the answers to many other questions. For those of you who already know this material, let it serve as a review.

Why are we interested in bacteria? Because some bacteria are capable of waging war on the human race and some bacteria are capable of benefiting our lives. We need to know the difference.

Bacteria are microorganisms and microorganisms are the smallest of all organisms; for example, 2,000 of them can be lined up across the head of a common pin. In this subcourse, we will be concerned with those tiny organisms that are unfriendly, because they are responsible for a large percentage of spoilage in foods. We believe it is important to know about those microorganisms that cause food deterioration so that we can eliminate deterioration in foods before it occurs.

Subcourse Components:

This subcourse consists of three lessons.

Lesson 1, Introduction to Microbiology.

Lesson 2, Food Microbiology.

Lesson 3, Food Preservation.

Credit Awarded:

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Branch at Fort Sam Houston, Texas. Upon successful completion of the examination for this subcourse, you will be awarded 8 credit hours.

You can enroll by going to the web site http://atrrs.army.mil and enrolling under "Self Development" (School Code 555).

A listing of correspondence courses and subcourses available through the Nonresident Instruction Section is found in Chapter 4 of DA Pamphlet 350-59, Army Correspondence Course Program Catalog. The DA PAM is available at the following website: http://www.usapa.army.mil/pdffiles/p350-59.pdf.

## LESSON ASSIGNMENT

**LESSON 1** Introduction to Microbiology.

**LESSON ASSIGNMENT** Paragraphs 1-1 through 1-26.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

1-1. Identify the definitions of common terms related to microbiology.

1-2. List various parts of the culturing process of microorganisms.

1-3. List five organisms of the Kingdom Protista.

1-4. Identify bacteria morphology and physiology, to include shape, size, arrangement, reproduction, and optimum growth conditions.

1-5. Identify characteristics of microorganisms smaller than bacteria and molds, yeasts, and enzymes.

1-6. List the steps of microbial growth.

1-7. List the four phases of microbial growth and four ways to lengthen the lag phase.

1-8. Identify factors influencing growth of microorganisms, to include nutritional requirements, oxygen requirements, pH requirements, temperature requirements and the effect of heat or cold, and moisture requirements.

1-9. Identify terms used in relation to inhibiting or destroying microorganisms.

**SUGGESTION** After studying the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## LESSON 1

## INTRODUCTION TO MICROBIOLOGY

### Section I. AGENTS CAUSING FOOD SPOILAGE

### 1-1. INTRODUCTION

a. **Early Man and Food.** The history of man's civilization can be directly correlated with his knowledge of the science of the preservation and curing of foods. Preserving and curing food is directly related to the microbiology of the particular food. While Early Man had no conclusive evidence of the existence of microorganisms, he did know that food would spoil under certain conditions, and he was able to take certain corrective measures to prevent this spoilage. Man must have a constant source of food in order for civilization to advance. The human race has lived under two different nutritional systems. Under the first system, which terminated about 6000 B.C., man was essentially a food gatherer. He was concerned only with obtaining food to continue to exist and was not able to gather or produce food in sufficient quantities so that there was leisure time for cultural pursuits. About 6000 B.C., man became a food producer. Food then became available in sufficient quantities so that there was sufficient food for periods of leisure and, in fact, certain groups were freed of the necessity of producing food and were able to become scholars. Cereal and livestock farming are essential to the founding of civilization. With the growing of cereals and domestication of livestock, man finally achieved the status of a food producer.

b. **The Necessity of Preserving Food.** Man, as a food producer, was able to settle in one locale and remain there on a permanent basis. The food he produced, of course, was subject to spoilage and he had to become adept at preserving it. Cereals were stored so as to alleviate the losses caused by insects. Gradually, the science of preserving meat products evolved, so that it was possible to slaughter animals and not be compelled to eat the meat within a twenty-four to forty-eight hour period.

c. **Snow and Ice.** Snow and ice have been used for many centuries to preserve meat products. Alexander the Great used snow to preserve food, and also used it to cool his wine. The Romans used snow to pack prawns (resembling shrimps) and other perishable foods. Chaff was often mixed with the snow to slow down the rate of melting. Such a mixture of snow and chaff was obviously unsanitary because microorganisms are not destroyed in such a mixture.

d. **Salt.** Salt has been used as a preservative since the beginning of recorded history. It was used in China as early as 1200 B.C. The Jews were early users of salt to preserve meat products. This would seem natural because of their access to the supply of salt from the Dead Sea. Salt-fish was a common commodity in Ancient Greece. The Romans were schooled in the use of salt as a preservative by the Greeks. The Romans used it in preserving fish and pork products.

e. **The Roman Food Supply System.** The Romans became very adept at curing and preserving meat products. They established slaughter facilities and meat shops that were much superior to those found in any other part of the world. Julius Caesar was able to supply his legions with meat and other food products because of the efficient manner in which food was processed, stored, and distributed in Rome. It is presumed that the conquest of Gaul was made possible by the logistical advantage held by Julius Caesar. The Romans were able to engage in sustained combat, whereas the Gauls had to disperse in small units after each engagement to obtain food supplies. A system of supply such as the Gauls had did not enable them to face the Romans in sustained combat.

f. **Honey.** The Greeks and Romans used honey as a preservative. Honey was also used in combination with vinegar and other ingredients. Honey, because of its high sugar content, inhibited the growth of microorganisms, and imparted a desirable taste. Honey, combined with vinegar, salt, and other ingredients, resulted in a sweet pickling solution resembling our sweet pickling process used today.

## 1-2. DEFINITIONS

a. **Microbiology.** Microbiology is the study of microscopic organisms including bacteria, rickettsiae, viruses, yeasts, molds, and protozoa. These organisms are too small to be seen without the assistance of a microscope. They are also known as microbes or microorganisms. One must have an understanding of basic microbiology in order to take advantage of the beneficial actions of microorganisms and to counter their undesirable effects. The preservation and curing of meats is nothing more than the commercial adaptation of the knowledge of the nature, life, and actions of microorganisms gained in the classroom and the laboratory. The microorganisms that cause the problems in food spoilage are bacteria, yeasts, and molds.

b. **Bacteriology.** Bacteriology is the study of bacteria, and more specifically, the study of the chemical and biological properties of bacteria.

c. **Virology.** Virology is the study of viruses.

d. **Mycology.** Mycology is the study of fungi, including yeasts, and molds.

e. **The Potential of Hydrogen (pH).** The potential of hydrogen (pH) is a mathematical expression of the degree of acidity or alkalinity, ranging from 0 to 14, with pH 7 as the neutral point. A pH below seven, indicates acidity and above seven, alkalinity. Therefore, the lower the pH below 7, the greater the acidity; the higher the pH above 7, the greater the alkalinity.

f. **Pathogenic.** Pathogenic is a term meaning disease producing.

g. **Organoleptic.** Organoleptic (sensory evaluation) relates to or involves the use of the sense organs in the subjective testing (flavor, odor, appearance) of food products.

## 1-3. MICROORGANISMS

Microorganisms are living things so small that they can be seen individually only with the aid of a microscope. They are widely distributed in nature and are responsible for many physical and chemical changes of importance to plants, animals, and humans.

a. **Pathogenic and Nonpathogenic.** Most students understand that not all microorganisms are harmful or pathogenic (disease producing), but they do not fully appreciate the fact that microorganisms make possible the continuing existence of plants and animals on our earth. In addition, many different kinds of microorganisms are used by industry to manufacture products of great value to a man such as antibiotics (penicillin) and various food products, including cheese, bread, and wine. However, the activities of nonpathogenic microorganisms are not always desirable. Food products may be spoiled, fabrics and fibers may be rotted, and fermentation processes may be upset by nonpathogenic but undesirable microorganisms.

b. **More Research Needed.** We are interested in microorganisms because of their disease producing potential and because they are capable of causing both good and bad physical and chemical changes in food, clothing, and the general environment. We are also interested in ways and means of controlling undesirable organisms and utilizing efficiently the activities of those that are beneficial. A study of the activities and means of controlling microorganisms must be based upon the knowledge of their nature, life, and actions.

c. **Culturing Microorganisms.** Microorganisms can be cultured (grown) for study in a specially prepared medium. Various activities or procedures have been developed in order to grow and isolate certain species of microorganisms. Microorganisms need nutrients in order to live and grow. The food source used in laboratories for growing microorganisms is called a culture medium. This medium includes an organic carbon source, a nitrogen source, inorganic minerals, and any other nutrients needed. The required nutrients are usually specific nutrients based on the physiological needs of the particular species of organism being cultured; i.e., certain amino acids, purines, pyrimidines, and vitamins. For many bacteria, a single compound (such as amino acid) may serve as an energy source, carbon source, and nitrogen source. Others require a separate compound for each.

(1) <u>Liquid or solidified culturing media</u>. These culturing media must be moist since nutrients can only enter the microorganisms by virtue of diffusion or osmosis. The culturing material can be either liquid media or solidified media. Liquid culture media are referred to as nutrient broth and are made and kept in test tubes, while solidified media are made and kept in either test tubes or petri dishes. Agar is added to nutrient broth to solidify the media. Agar is a polysaccharide extract obtained

from seaweed and is uniquely suitable for bacterial cultivation because of its general resistance to bacterial action and its property of dissolving at 212ºF (100ºC), but not gelling until cooled below 113ºF (45ºC). It is heated to a liquid, poured either into test tubes or petri dishes and allowed to cool. When the agar media cools and gels, it is ready to have microorganisms placed on it (inoculated). Also, bacteria can be suspended in the agar while it is still a liquid. Both nutrient broth and nutrient agar media may or may not have special nutrients added, depending upon the needs of the species of microorganisms that are to be cultured.

(2) In test tubes. When agar is placed in test tubes, the contents are allowed to either gel in an upright position or are slanted to create a larger surface area. The former are called "deeps" and are usually inoculated by placing microorganisms on a needle and stabbing the media. The latter are called "slants" and are inoculated by smearing organisms across the surface of the agar.

(3) In petri dishes (plating). Plating is the process of inoculating microorganisms on the surface of the agar media in petri dishes. This method is most often used to grow large populations of organism colonies for further study. After the agar plates have been inoculated, they are kept at temperatures optimum for the growth of the organisms. The act of establishment, growth, and multiplication of microorganisms at a specific temperature for a given time is termed incubation. Following the establishment of organisms on agar media, the colonies and media together are termed a culture.

## 1-4. EARLY DEVELOPMENTS IN MICROBIOLOGY

a. **Leeuwenhoek.** Anton Van Leeuwenhoek was the first man to see microorganisms. He ground lenses as a hobby and made his discovery while observing a drop of water. Seeing many tiny organisms moving rapidly under the lens, he called them "animalcules" (little animals). He is credited with inventing the microscope, and his invention made possible the development of the science of microbiology. Leeuwenhoek continued to work with microscopes until his death in 1723 and made many important discoveries. He observed bacteria on houseflies; he saw bacteria in the excreta of man and animals; and he discovered the presence of bacteria in the human mouth.

b. **Koch.** Robert Koch was another important worker in the field of microbiology. He proved that bacteria cause disease by discovering the causative organisms of anthrax, cholera, and tuberculosis.

c. **Pasteur.** Louis Pasteur is credited with being the founder and originator of the science of microbiology. He immunized sheep against anthrax and introduced a treatment for the prevention of rabies. Our pasteurization process for milk and other foods also bears his name.

d. **Others.** There have been many important contributions to microbiology and many esteemed workers in this field; however, Leeuwenhoek, Koch, and Pasteur are the individuals who were most important in establishing microbiology as a science.

## 1-5. CLASSIFICATION OF ORGANISMS

a. **Animal.** Most animal cells have flexible outer walls, and therefore, they are usually able to move independently.

b. **Plant.** Plant cells usually have rigid outer walls of cellulose, which surround the living protoplasm within the cell and maintain the cell shape. Unlike animals, most plants are either attached to one spot by their roots or are transported by their environment, as, for example, the liquids in which they are suspended. Plants get their energy from the process known as photosynthesis, with chlorophyll acting as a catalyst.

c. **Protista.** The only basis for an organism being classified as a member of the kingdom Protista is its simple biological organization, characterized by a lack of extensive tissue formation. However, some organisms have a tendency to form tissues, and it is difficult to classify these organisms with great certainty. The kingdom includes both microscopic unicellular organisms and very large multicellular forms. Included in the kingdom Protista are all bacteria, fungi, rickettsiae, viruses, and protozoa.

(1) Fungi. Fungi are organisms that are not photosynthetic. They are multicellular, consisting of long filaments.

(2) Bacteria. Bacteria are one-celled microorganisms. They differ in shape from ball-or round-shaped, to rod-shaped, to curved or coil-shaped. Shape is an important characteristic of bacteria because it plays a key role in laboratory identification. The ball- or round-shaped bacteria are called cocci; the rod-shaped are known as bacilli; and we call the curved or coil-shaped ones spirochetes.

(3) Rickettsiae. These are bacteria that can survive only in living cells. Unlike most infectious agents, rickettsiae require an intermediate host or vector in order to be transmitted from one host to another. Some of the common vectors include fleas, lice, ticks, and mites. Rickettsiae are smaller than most other bacteria. They may appear as cocci, diplococci (cocci in pairs), or short bacilli.

(4) Viruses. A virus is a noncellular, submicroscopic particle that lives and reproduces in living cells. Like bacteria, viruses have many sizes and shapes that are significant factors in their laboratory identification. In size, the virus is the smallest of all infectious agents and must be viewed with an electronic microscope. Filtration is the method usually employed to separate bacteria from viruses, which may be present in animal or plant fluid. Filters catch the bacteria but let the viruses pass through.

(5) Protozoa. A protozoan is a microscopic, unicellular organism without chlorophyll. They (protozoa) get their energy from organic matter.

## 1-6. SIZE RELATIONSHIP

Special units of measurement are used to state the size of microorganisms. Size is usually measured in microns and the symbol for micron is μ, the Greek letter mu. A micron is equivalent to 1/1000th of a millimeter or 1/25,400th of an inch. To give you a better idea of the size of a micron, the diameter of a metal pinhead is about 2000 microns. The range in size of bacteria is wide. Some cells are so small that they can barely be seen by the best compound light microscopes whereas others are large enough to be almost visible with the unaided eye. Among the ball- or round-shaped bacteria, the diameter varies from 0.5 to 2.5 microns. The variations are much greater in the rod-like species--from 0.2 to 2.0 microns in width and from 1 to 15 microns in length. Most of the bacteria of importance in foods range from 2 to 10 microns in length and 0.5 to 2.5 microns in diameter. The size of viruses is much smaller, the largest being about 0.2 micron and the smallest about 0.012 micron.

## 1-7. BACTERIA MORPHOLOGY AND PHYSIOLOGY

a. **Definition.** Bacteria are microscopic, unicellular microorganisms, containing no well-defined nucleus. Most bacteria are devoid of chlorophyll and reproduce asexually by division (binary fission).

(1) The cell (figure 1-1) is the structural unit of all living organisms. The typical cell is composed of cytoplasm surrounded by a cell wall, and there is a nucleus near the center of the cell. Because of their small size and controversial nature, there is no generally accepted opinion that the bacterial cell has a nucleus. The outer part of the bacterial cell is made up of three structures we call the cell wall, the cytoplasmic membrane, and the capsule. The cell wall limits the volume occupied by the cytoplasm and gives shape and rigidity to the cell. Inside the cell wall is the cytoplasmic membrane that surrounds the cytoplasm.

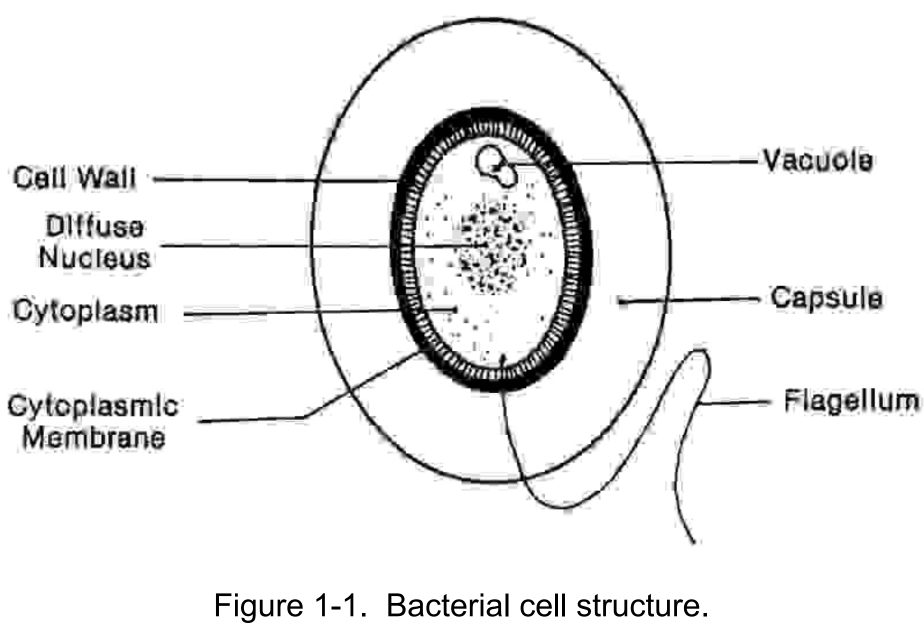


Figure 1-1. Bacterial cell structure.

(2) The capsule is a gummy, jelly-like layer that surrounds most bacteria and varies in thickness. This capsule offers the cell some protection against adverse conditions, including drying. The capsule is the source of slime on beef carcasses.

(3) Cytoplasm is the internal environment of the cell, excluding the nucleus. This is part of the actual living materials of the cell and the physical and chemical changes that occur here produce life. A highly specialized structure in the cytoplasm is the site of respiration of the cell. The cytoplasm is usually a clear, somewhat viscous substance consisting of a complex mixture of proteins, fats, oils, carbohydrates, minerals, and water.

(4) The nucleus or aggregates of nuclear material are in the central portion of the cell. They transmit hereditary traits and contain the genetic controlling materials.

(5) Flagella are long, fine thread-like filaments attached to the cell in various locations and they give movement or locomotion to the cell. Not all bacteria possess flagella.

(6) Endospores are produced by some bacilli (rod-shaped bacteria). The endospore enables the bacterial cell to remain viable for long periods of time. It is much more resistant to drying and other adverse conditions than the vegetative cells of the species. Some bacterial spores are so resistant that they will live 20 years or more on dry splinters of wood. They will grow after being subjected to strong disinfectant solutions, and will survive for an hour in boiling water or a hot oven. The biologic significance of endospores is not known, but because of their great resistance to heat, drying, and chemicals, some bacteriologists argue that spores are produced to permit survival under unfavorable conditions.

b. **Shape and Size.** Bacteria are spheroid, rod, or spiral in shape (figure 1-2). Spheroid (or round-shaped) bacteria are called cocci (singular: coccus), rod-shaped bacteria are called bacilli (singular: bacillus), and spiral-shaped bacteria are called spirilla (singular: spirillum). See figure 1-2. The organisms causing food fermentation, the soil bacteria, and most of the rot-producing bacteria are in the bacilli classification. The extreme smallness of bacteria may be emphasized by the fact that 400 million bacteria would occupy the volume of a grain of sugar. Bacteria are commonly magnified about 1000 times for observation in the laboratory. A man magnified to the same extent would be over a mile high and 500 yards wide.

c. **Arrangement.** Cells possessing a well-developed slime layer, or capsule, tend to cling together, but cells without a capsule exist as single cells. Bacilli and spirilla are arranged in chains, in irregular masses, or they may exist as single cells. Cocci may exist as a diplococcus (paired), streptococcus (pairs or chains), staphylococcus (clusters), tetracoccus (square clusters of four), or sarcina (cube clusters of eight with formation of yellow or orange pigment). See figure 1-2. Bacteria often develop colonies that are large enough to be seen without the aid of a microscope. These colonies are simply masses of bacterial cells that may develop from a single vegetative cell, a single spore, or a clump of cells or spores. Each cell functions as an independent unit. Colonies of a bacterial species will generally exhibit a distinctive and characteristic form and color.

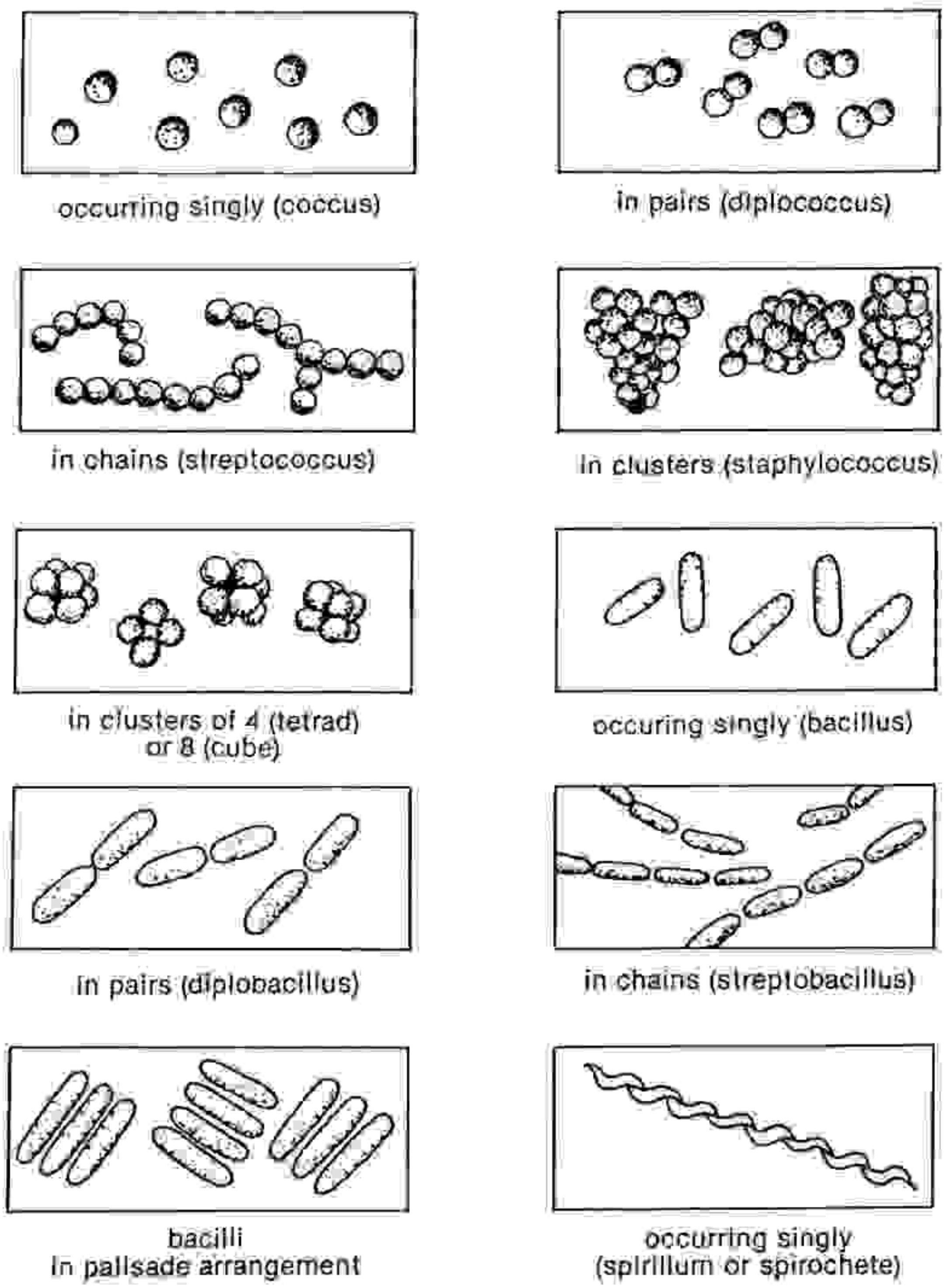


Figure 1-2. Shapes and arrangements of bacteria.

d. **Reproduction.** Most bacteria reproduce by binary fission. One organism divides to form two new organisms. The time required for fission will vary from eight minutes to as long as six hours. If all cells of each succeeding generation divided every twenty minutes, then one bacterial cell would result in sixty-five billion cells in twelve hours.

e. **Optimum Growth Conditions.** Bacteria generally have a poorer tolerance for salt and sugar than most other microorganisms. Most species of bacteria have an optimum pH range between pH 6.0 to pH 8.5. Bacteria generally will not grow in as wide a range of moisture conditions and temperatures as will yeasts and molds.

## 1-8. MICROORGANISMS SMALLER THAN BACTERIA

There are two groups of microorganisms smaller in size than most bacteria. They are of little importance as spoilage organisms but are of considerable importance as pathogenic organisms in food.

a. **Rickettsiae.** Rickettsiae are smaller in size than other bacteria but are larger than viruses. Rickettsiae cause such diseases as typhus, Rocky Mountain spotted fever, and Q fever. Q fever is now considered to be one of the major milk-borne diseases in this country.

b. **Viruses.** Viruses are our smallest group. They cause many diseases in animals, humans, and plants. A bacteriophage is a type of virus that destroys bacteria. Bacteriophages are very important in the brewing industry and dairy industry, since they will destroy beneficial bacteria that are essential to the fermentation and souring process.

## 1-9. MOLDS

Molds (division Eumycetes) are multicellular microorganisms that form filamentous branching growths known as mycelia (singular, mycelium). See figure 1-3.

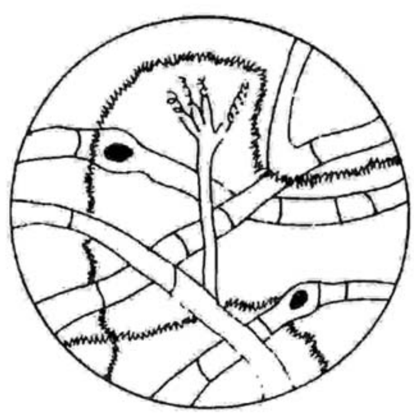

Figure 1-3. Molds.

Individual mold cells have rigid walls surrounding the protoplasm. The cells are often cylindrical, and they vary greatly in size. Molds can be seen with the naked eye when they grow in sufficient quantities. Molds multiply by spore formation. They are usually found growing on solid substances such as wood, paper, cloth, leather, meat, fruits, vegetables, and many other substances. Molds have definite colors such as white, black, and green. They can grow in foods containing high percentages of sugar and salt. Molds are capable of growing in a pH range of 2.0 to 8.5. Molds can grow at a temperature as low as 15ºF (-9.45ºC), and a moisture content as low as 6 percent. They produce large numbers of spores that are light in weight and are easily transported by air currents. Molds are responsible for a wide variety of losses in food products, but they are also desirable in several industrial processes (penicillin production) and are responsible for the appearance and flavor of cheeses such as Roquefort and Bleu.

### 1-10. YEASTS

Yeasts (figure 1-4) are unicellular organisms that are rather large when compared to bacteria. Like the molds, the yeasts belong to the division Eumycetes. Yeast cells are spherical, elliptical, or cylindrical. The protoplasm of a yeast cell is enclosed by a cell wall and cytoplasmic membrane. It contains a nucleus but there are no flagella present for locomotion. They reproduce by budding and have the ability to ferment sugars and to produce alcohol and carbon dioxide. They can grow in higher concentrations of salt and sugar than bacteria are able to tolerate. They prefer an acid medium of pH 5.5 to 6.5. Yeasts need more moisture (15 percent) than molds but require less moisture than bacteria. Yeasts are capable of growing at lower temperatures than most species of bacteria. Generally speaking, yeasts occupy a position intermediate in range between molds and bacteria relative to their tolerance for extremes of sugar, salt, acid, moisture, and temperature. Yeasts are important in bread making and the manufacture of alcohol.

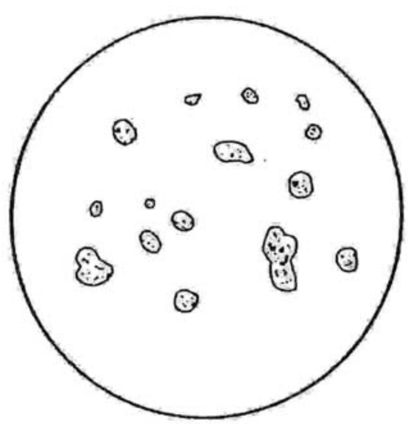

Figure 1-4. Yeasts.

## 1-11. NUTRITION AND METABOLISM OF MICROORGANISMS

Microorganisms require food for energy and for growth. Food is required for energy for synthetic activities, for moving, and to maintain the living state. Food for growth is required to manufacture protoplasm. Microorganisms must have their food in solution in order for it to pass through their cell membranes. If they are not growing in a liquid medium, then the microorganisms will secrete extracellular enzymes that will liquefy their food.

## 1-12. ENZYMES

Enzymes are organic substances that cause chemical reactions without being consumed in the reaction; therefore, they are called <u>organic</u> <u>catalysts</u>. They are produced by living cells and then become independent of the cells. They are incredibly active; e.g., one molecule of the yeast enzyme can catalyze the conversion of an inconceivably large number of sugar molecules into ethyl alcohol; and they are very specific, that is, they act upon only one substance. Extracellular enzymes are formed inside the cell and diffuse through the cell wall to cause their action. These enzymes bring about digestion in the human body and putrefaction (decomposition) in fruits, vegetables, and meats. Intracellular enzymes are formed in and remain within the cell.

a. **Characteristics.** Enzymes are usually named according to the kind of substances upon which they act or the kind of chemical reaction they produce. They are suffixed "ase" as in the case of "carbohydrase," an enzyme that acts upon carbohydrate. As we have already stated, enzymes are specific; thus, maltase, a carbohydrase, is the specific enzyme that converts maltose into glucose.

b. **Effect of Temperature.** Within certain limits, the speed of reactions caused by enzymes is doubled for each 18ºF or 10ºC rise in temperature. A 50 percent reduction in enzymatic action will result when the temperature is lowered 18ºF or 10ºC. This is referred to as van't Hoff's law or temperature quotient (known as Q10). Activity is best at temperatures between 32º-104ºF (0º - 40ºC).

c. **Example of Enzyme Action.** As mentioned above, enzymes can initiate a considerable amount of activity. They initiate reactions without being consumed. For instance, the enzyme invertase (which changes sucrose into dextrose and levulose) will invert one million times its own weight of sugar and will be capable of more activity.

d. **Similarity to Living Cells.** Enzymes possess some of the properties of living cells. Living cells are destroyed by high temperatures. Enzymes are inactivated by high temperatures and most of them are destroyed by a temperature of 165ºF (74ºC). Living cells have optimum temperatures for their functions, and enzymes have optimum temperatures for their actions. The actions of living cells are slowed at low temperatures; the actions of enzymes are retarded by low temperatures. Enzymes and living cells both require certain pH limits for their optimum actions.

e. **Use of Enzymes in Cheesemaking.** In order to make cheese, the casein of the milk must be coagulated by natural souring or by the use of rennet, a commercial preparation of the enzyme rennin that is extracted from the calf's stomach. After the curd is coagulated, it is then acted upon by microorganisms to produce the desired flavor.

f. **More Examples of Enzyme Action.** After death, the tissues of the animal undergo a partial autolysis by enzymes contained in the tissues. Tenderizing of the meat is accomplished by the action of these autolytic enzymes. Papain, a proteolytic enzyme of papaya, is used as a meat tenderizer. Bromelin, a similar enzyme in fresh pineapple juice, is equally effective as papain and has a more desirable odor.

## 1-13. SUMMARY

a. **The Action of Microorganisms.** Many kinds of microorganisms are most desirable for the part they play in preserving and processing foods. On the other hand, some microorganisms attack food. Microorganisms such as bacteria, molds, and yeasts damage or destroy foods. Bacteria produce certain enzymes that have either a beneficial or a destructive effect on some foods. Bacterial growth in or on foods often is extensive enough to make the food unattractive in appearance or objectionable in some other way. Some bacteria cause food poisoning, some produce bitter flavor, and others cause foods to spoil in one way or another. Molds cause some foods to decompose. The fermentation effect of yeasts causes spoilage among many kinds of foods.

b. **Microorganisms and Enzymes.** Microorganisms include bacteria, molds, yeasts, rickettsiae, and viruses. Enzymes are not included among the microorganisms. An enzyme is an organic catalyst.

# Section II. MICROBIAL GROWTH

## 1-14. INTRODUCTION

Many species of bacteria increase in numbers very rapidly under ideal conditions. Many scientists believe that the rapid growth of bacterial cells is because of their large surface-to-volume ratio. In order to maintain their small size and the favorable surface-to-volume ratio, cell division must occur rapidly. Most living organisms have a cellular structure and grow by an increase in the number of cells per organism. Bacteria, however, retain their unicellular structure and growth is reflected in an increase in the number of individual cells, or organisms. Cell division of unicellular bacteria appears to follow a very similar pattern and occurs in four steps.

a. **Step 1.** The cell nucleus divides before the cell division occurs.

b. **Step 2.** The second step is the division of the cytoplasm into two equal parts separated by an inward growth of the cytoplasmic membrane forming a cross plate. In cylinder-shaped bacteria, this division is generally at right angles to the long axis.

c. **Step 3.** The third step involves formation of a cross wall which grows inwardly from the cell wall and splits the cross plate so that each of the newly formed cells has a continuous cytoplasmic membrane. The cross wall then divides, providing each daughter cell with a complete cell wall.

d. **Step 4.** The last step in cell division is the separation of the sister cells. The cells of many bacterial species separate shortly after the cross wall is formed. Such bacteria generally appear as single cells and form smooth colonies on solid culture media. Other species have a cell wall which does not tend to split between cells and which withstands the stresses induced by continued growth. Such bacteria do not separate easily and form chains or other groupings such as sheets, packets, or irregular clumps. Colonies from rod-shaped bacteria forming long chains generally appear rough or wrinkled because of the buckling of the chains as they meet resistance to their continued elongation.

## 1-15. CELL GROWTH

If conditions are favorable, cell division is normally followed by a period of cell growth or enlargement. The cell grows to its original size through absorption of water and food and through manufacture of protoplasm. This growth is at right angles to the plane in which the division takes place. Quite naturally, during such a period of cell division and growth in a culture, the new cells are only half as long as the mature cells. In some spherical or coccus forms, the new daughter cells are hemispheres when first formed and are then restored to full spheres through growth. In some short rod cells, the cell elongates first and then divides.

## 1-16. GROWTH CURVE

Growth of microorganisms refers to an increase in the number of unicellular organisms. Under favorable conditions of nutrition, oxygen, pH, moisture, and temperature, some kinds of bacteria may double in number about every 20 minutes. This time interval is called generation time. Simple arithmetic shows the magnitude of the result if this rate of increase were to continue for only a few days. Fortunately, there are several factors that help control the situation. In some cases, the food supply may become depleted or the accumulation of waste products may slow the process. However, when these conditions are controlled by the continuous addition of nutrients and removal of waste products, the bacterial population always reaches a maximum before the medium in which it is growing becomes a solid mass of cells.

a. **Four Phases.** Different species of bacteria show various shapes of growth curves depending on the generation time and the maximum population attainable under the prevailing growth conditions. The growth curve is determined by plotting the numbers of bacteria per milliliter of culture against incubation time. The counts are plotted with logarithms of numbers. The growth curve of microorganisms is composed of four phases (figure1-5).

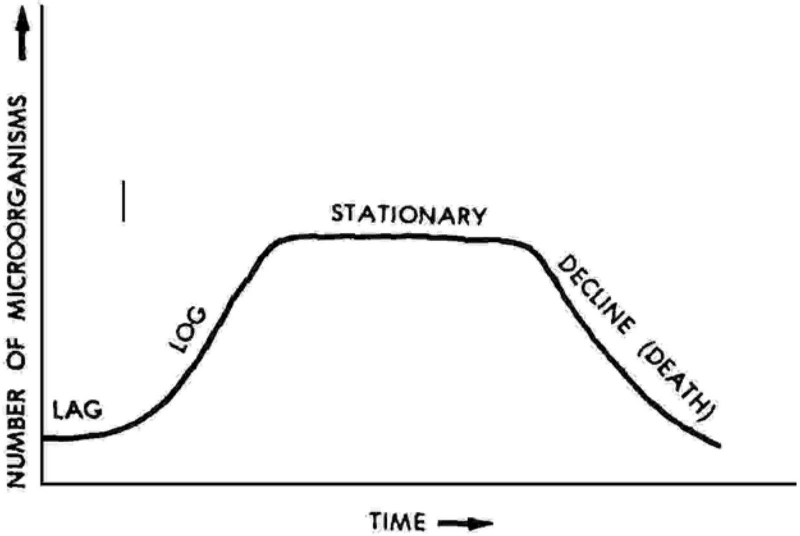


Figure 1-5. Growth curve of microorganisms.

(1) During a period of one to several hours, there is a lag phase in which there is little or no increase in cell numbers. During this phase, the cells are becoming adjusted to a new environment.

(2) The log (logarithmic) phase is a period of rapid growth. The growing cells divide and continue to do so at regular intervals until maximum growth can be supported. In this phase, the microorganisms are well adjusted to their environment and are able to multiply rapidly.

(3) The stationary phase is one in which the population remains unchanged. The rate of reproduction equals the death rate in this phase.

(4) The decline (death) phase occurs when the death rate exceeds the rate of reproduction.

b. **Ways to Lengthen the Lag Phase.** Growth control is important in food preservation. Prevention or delaying food spoilage is accomplished by lengthening the lag phase as much as possible. This can be done in several ways:

(1) By the introduction of as few spoilage organisms as possible, that is by reducing the amount of contamination. The fewer organisms present, the longer the lag phase.

(2) By avoiding the addition of actively growing organisms, which may be growing on unsanitary containers, equipment, or utensils with which food comes in contact.

(3) By control of one or more unfavorable environmental conditions such as nutrients, moisture, pH, or temperature. The greater the number of conditions that are unfavorable means the longer the delay of the beginning of cell growth.

(4) By damage to organisms through processing methods such as heat or irradiation.

## 1-17. FACTORS INFLUENCING GROWTH OF MICROORGANISM

There are several factors that influence the growth of microorganisms: nutrition, oxygen, pH, temperature, and moisture. Lack of food retards bacterial growth, and growth is favored by a sufficient quantity of the proper kind of food. Moisture is required to carry foods in solution into the cell, to carry wastes in solution away from the cell, and to maintain the moisture content of the cytoplasm. Temperature has a profound influence on the growth rate of microorganisms. Microorganisms subjected to adverse temperatures are either destroyed or are not able to multiply. The optimum temperature of a microorganism is the temperature that provides for the most rapid growth of that microorganism. The pH of the medium in which microorganisms grow exerts a considerable influence on their rate of growth. All microorganisms have an optimum pH at which they grow best. Most species of bacteria have an optimum pH between 6.0 and 8.5. Molds will grow in a pH range between 2.0 to 8.5. Yeasts have an optimum pH range from 5.5 to 6.5.

## 1-18. NUTRITION

Nutrients or foods are substances which are outside the cell and which, upon entering a cell after passing across the cell membrane, can be used by the cell for building material or for obtaining energy. Food requirements of bacteria show great variations from species to species. Some organisms can obtain all their food requirements from inorganic matter while others need many complex organic compounds. Although any one species may be able to use only a small number of materials as sources of food, bacteria as a group are able to utilize all the naturally occurring organic compounds as well as many inorganic substances.

a. **Requirements.** Bacteria require foods for the same purposes, as do other forms of life, namely, as sources of material for cellular synthesis and for energy in order to perform these synthetic processes. Requirements include carbohydrates (sugar, starches, and celluloses), a source of nitrogen, vitamins, water, and a source of energy.

b. **Sources.** The majority of bacteria species use naturally occurring organic materials such as carbohydrates, proteins, fats, and so forth, not only as sources of carbon, hydrogen, oxygen, and nitrogen but also for the energy needed to synthesize these materials into protoplasm (that material referred to as the physical basis of life and which is common to all living cells). The requirements of most bacteria for inorganic materials can be satisfied by salts containing sodium, potassium, calcium, magnesium, iron, chlorine, sulphur, and phosphorus. More or less complex sources of carbon, hydrogen, oxygen, and nitrogen may be obtained from organic sources, inorganic compounds, or from the elemental forms of these substances.

c. **Deficiencies.** Many bacteria have deficiencies in their synthetic abilities that must be overcome before growth can follow. The vitamin B complex is the most common source for this compound requirement. Other compounds often found necessary for maximum growth are the amino acids, which are the building blocks of protein.

d. **Methods.** There are two primary methods by which bacterial species secure their food material. On this basis, bacteria are classified as follows:

(1) Saprophytes. These bacterial species get their food materials from the dead bodies and waste materials of plants and animals. They also make some use of inorganic compounds such as ammonia, nitrates, chlorides, phosphates, and sulfates. Most of the saprophytes are harmless to man. Two exceptions are Clostridium botulinum and Clostridium tetani.

(2) Parasites. These bacterial species secure their nourishment from the cells of plants or animals with which they intimately live. The parasitic bacteria are mostly harmful to man.

## 1-19. OXYGEN REQUIREMENTS

Few processes have had such a wide variety of definitions as respiration. We normally think of respiration as being synonymous with breathing, but a broader meaning is necessary to identify bacterial respiration, which is accomplished without a breathing apparatus. Bacterial respiration is any chemical reaction whereby energy is released for life processes. The reactions are those that transform energy for the cell. Energy transformations can take place under aerobic or anaerobic conditions or combinations of these conditions. On the basis of their processes of respiration, bacteria are classified as follows:

a. Aerobic bacteria require the presence of free or atmospheric oxygen for growth.

b. Anaerobic bacteria do not require the presence of oxygen for growth and will grow better in its absence.

c. Facultative bacteria will grow either with or without the presence of oxygen.

d. Microaerophilic bacteria require a definite but reduced amount of free oxygen for growth.

## 1-20. ACIDITY AND ALKALINITY

a. **Foods and the pH Scale.** Most bacteria are sensitive to changes in the acidity or alkalinity of their environment. Acidity and alkalinity are determined by the concentration of the hydrogen ion. The symbol for the logarithm of the reciprocal of the hydrogen ion concentration is pH. The pH scale extends from 0 to 14 with a pH of 7.0 being neutral. A solution is acidic because of an excess of positively charged hydrogen ions or it is alkaline because of an excess of negatively charged hydroxyl ions. Numbers below 7.0 on the pH scale indicate an acid condition with 1.0 or less being the most acid. Numbers above 7.0 on the pH scale indicate alkalinity with 14.0 being the most alkaline.

(1) Foods have been categorized according to their pH as follows:

| | |
|---|---|
| High-acid foods | pH below 3.7 |
| Acid foods | pH 3.7--4.6 |
| Medium-acid foods | pH 4.6--5.3 |
| Low- or non-acid foods | pH over 5.3 |

(2) The approximate pH values for selected foods are listed below. The pH values are only approximations, since there is considerable variation in the pH of some foods and the pH of foods and the pH of food products can change during ripening, processing, or spoilage.

| | |
|---|---|
| Lemons | 2.2--2.4 |
| Apples | 2.9--3.5 |
| Tomatoes | 3.7--4.9 |
| Spinach | 5.1--6.8 |
| Milk | 6.3--6.8 |
| Shrimp | 6.8--8.2 |

b. **The Optimum pH Range for Bacteria.** Bacteria have an optimum range in which they grow and function best. For many, this is near the neutral point or in a pH range of from 6.0 to 8.5. Some bacteria can live in or even require a very acid environment such as a pH of 3.0 or less. Some bacteria prefer an alkaline pH of 8.0 or higher. An important phase of bacterial physiology is the determination of the optimum, minimum, and maximum pH for organisms being investigated.

c. **The Optimum pH Range for Molds and Yeasts.** You will recall that molds can grow over a wider range of pH values than can yeasts, as evidenced by the difference in range of ph values: molds from 2.0 to 8.5, and yeasts from 5.5 to 6.5. Bacterial growth is favored by a near neutral pH. An example of the importance of knowledge about pH values and food microbiology is that the food organism Clostridium botulinum prefers a near neutral pH for growth and its growth is inhibited by increased acidity.

## 1-21. TEMPERATURE

a. **Growth Range.** Bacteria as a group are able to grow over a range of about 175-Fahrenheit degrees (F). This is a relatively narrow range when one considers the coldest arctic to the hottest volcano. However, it is a wide range when compared to the changes acceptable in man's body temperature. No one bacterial species can grow over the entire 175-degree range but some are capable of growing over about one-half of it; that is, from near 32ºF (0ºC) to 104º to 113ºF (40º to 45ºC). Each organism can grow only within a growth temperature range characteristic of the species.

(1) Minimum growth temperature. The lowest temperature at which growth occurs is the minimum growth temperature. This is difficult to determine because physiological activities gradually decrease with the temperature until they can no longer be detected by ordinary means. The generation time may be increased from minutes to days or weeks.

(2) Maximum growth temperature. The highest temperature at which growth can take place is the maximum growth temperature. This is more readily defined and can occasionally be determined within a Fahrenheit degree.

(3) Optimum growth temperature. The temperature at which most rapid multiplication occurs is the optimum growth temperature. It is the point at which the generation time is the shortest. This may also be difficult to define because it may be altered by both chemical and physical factors. There is no one temperature that is optimal for all activities of the cell.

b. **Three General Groups.** Bacteria have been divided into three large groups on the basis of their growth temperatures. These groups are not sharply defined and the distinctions are arbitrary, but the classification serves some practical purposes. The groups are called thermophiles, mesophiles, and psychrophiles.

(1) Thermophiles. Thermophilic bacteria are interesting because they prefer temperatures intolerable to most forms of animal life. Water at 113ºF (45ºC) is hot to the touch--hotter than the ordinary bath. Thermophilic bacteria grow best at temperatures above 113ºF (45ºC). We arbitrarily say that the temperature range for this bacterial group is from 113º to 140ºF (45º to 60ºC), although they may grow anywhere within the range of 104º to 176ºF (40º to 80ºC). Thermophiles are particularly troublesome in the dairy industry since they may grow most rapidly at pasteurization temperatures. They may also cause spoilage of canned foods, which are stored at elevated temperatures because the spores of some thermophilic bacteria are extremely resistant to heat and survive the ordinary canning processes.

(2) Mesophiles. Mesophilic bacteria are the ones that are most common, and they grow best at the moderate temperatures ranging from 65ºto 105ºF (18º to 41ºC). The minimum and maximum growth temperatures vary, for the most part, within the range 50º to 125ºF (10º to 52ºC).

(3) Psychrophiles. Psychrophilic bacteria have a temperature range from 32º to 50ºF (0º to 10ºC) with some species multiplying at temperatures as low as 23ºF (-5ºC) in solutions that do not freeze solid (brine and sugar solutions). Organisms that grow well at 32º to 41ºF (0º to 5ºC) are often encountered as causes of spoilage in refrigerated foods, but their rate of growth at such temperatures is usually slow and spoilage is not apparent unless storage is greatly prolonged.

c. **Narrow Growth Range.** The term microphile is used to designate bacteria that have a narrow range of temperature for growth. By that, we mean the maximum and minimum temperatures are relatively close together. Most microphiles are mesophilic, with a temperature range between 86º to 104ºF (30º to 40ºC).

d. **Characteristics.** Generally speaking, the optimum temperature is much closer to the maximum temperature than to the minimum temperature. When bacteria are submitted to temperatures a little above the maximum or a little below the minimum, they are not necessarily killed but may enter a relatively dormant state.

## 1-22. EFFECT OF HEAT

a. **Mesophilic Bacteria.** Most mesophilic bacteria are killed if heated in a liquid medium to 122º to 149ºF (50º to 65ºC) for a few minutes, say 10 minutes. Some bacteria (those classified in the genera Bacillus and Clostridium) may form spores, which are highly resistant to boiling. Boiling for minutes to hours does not destroy these bacteria. The spores of some species can withstand temperatures above the boiling point of water for a half hour or longer.

b. **Thermophilic Bacteria.** Thermophilic bacteria, which do not form spores and which are capable of withstanding temperatures of 140º to 158ºF (60º to 70ºC) for the time required to pasteurize milk, are called thermoduric. These cause considerable trouble in the milk-processing industry.

c. **Resistance Factors.** In determining the heat resistance of bacteria, the following factors are considered jointly:

(1) The temperature.

(2) The length of time during which the bacteria are exposed to the heat.

(3) Whether the bacteria are heated in a moist or a dry condition.

(4) The pH concentration of the medium in which the bacteria are heated.

(5) The other characteristics of the medium. For example, bacteria are killed at a lower temperature in water than in cream.

## 1-23. EFFECT OF COLD

Low temperatures do not necessarily kill bacteria. Multiplication ceases below the minimum growth temperature but the organisms may remain viable in the dormant condition for long periods. Growth and multiplication can resume when the temperature is raised to the normal range. The resistance of bacteria to low temperature provides a means of preserving many species for long periods without the necessity of frequent transfers.

a. **Bacteria Survival.** The survival of bacteria at low temperatures is important in the food industry. However, survival of bacteria in frozen foods can lead to trouble. Many years ago when ice was used for refrigeration on a wide scale, several outbreaks of typhoid fever were reported that apparently were caused by bacteria in natural ice used several months after the ice was harvested. Laboratory tests later showed that typhoid bacteria could live in ice as long as 22 weeks. Other intestinal pathogens possess similar survival power.

b. **Implications for Frozen Foods.** The tremendous expansion of the frozen food industry emphasizes the importance of bacterial resistance to low temperature. As we have stated previously, freezing is not necessarily a means of destroying pathogens in food. Freezing often destroys vegetative cells and frozen foods usually spoil more rapidly after thawing than in the original unfrozen food. Freezing is believed to damage the food tissues so that nutrient materials are released upon thawing to promote very active multiplication of surviving spoilage bacteria. Therefore, it is suggested that thawed frozen foods be used immediately or else discarded.

## 1-24. MOISTURE

Most bacteria are naturally aquatic creatures and therefore, are seldom harmed by an excess of water. Water is the vehicle by which bacteria, yeasts, and molds secure food and eliminate waste products. Most bacteria and yeasts prefer media of very high water content. Molds require much less water. Dehydration restricts the metabolic activities of bacteria and may lead to death, especially at room temperature (or above) and in the presence of oxygen. As you might expect, spores are much more resistant than vegetative cells. Generally speaking, bacteria can live only a short time without water. In conditions of less than 15 percent moisture, most bacteria will die and the growth of others will be inhibited. Dehydration is a means of preserving foods.

## 1-25. RADIATION

a. **Ultraviolet Light.** The rate of killing of microorganisms by radiation is dependent upon the intensity of the source, the distance from the source, the time of exposure, and the amount of shielding material. Some viruses and the spores of bacteria and molds are more resistant to ultra-violet light than are vegetative cells.

Although ultraviolet light has been used to sterilize air, water, and a variety of other materials, it has a disadvantage in these applications in that solid particles, even though microscopic in size, may shield microorganisms from the radiation. Ultraviolet lights are used in many meat-hanging rooms to reduce bacterial and mold contamination.

b. **Other Radiation Sources.** Ionizing atomic radiations such as alpha particles and x-rays are also harmful to microorganisms. In general, these types of radiation require more energy to kill bacteria than does ultraviolet light.

## 1-26. INHIBITION OR DESTRUCTION

Microorganisms are inhibited and destroyed by a wide variety of chemical agents and physical processes. Some of the terms used in relation to inhibiting or destroying microorganisms are: antiseptic, disinfectant, germicide, and sterilization. An antiseptic is an agent that inhibits the growth of microorganisms. A disinfectant or germicide is an agent that kills microorganisms. Sterilization is the process of freeing a substance of all living microorganisms.

a. **Factors.** There are a number of factors that have a direct influence on antiseptics, disinfectants, and sterilization. Concentration of the chemical agent is important. A high concentration will sterilize or disinfect in a shorter period of time. A 50 percent reduction in the concentration of a disinfectant will decrease its efficiency by a ratio of 1 to 4. Time of exposure to the agent is important. In no case is death to all organisms instantaneous, so the agent must be given enough time to complete its action. The number of organisms present is important. As a rule, it is more difficult to inhibit or kill large numbers of microorganisms than small numbers. This is particularly true if there is a wide variety of organisms present in large numbers. The kind of microorganisms present will determine the efficiency with which they are inhibited or destroyed. Spores are more resistant than vegetative cells. Encapsulated varieties of a species are more difficult to kill or inhabit than nonencapsulated varieties. The medium surrounding the microorganisms is an important consideration. Heat in the presence of moisture and dry chemicals in solution will kill more rapidly. Some substances in solution tend to protect microorganism, while other increase their susceptibility to antiseptics or disinfectants. Generally, microorganisms will be more resistant when the pH is one that is satisfactory for their growth. The efficiency of disinfectants increases as the temperature is raised.

b. **Physical Processes.** There are several physical processes that will inhibit or destroy bacteria. Desiccation is an important physical process. Dried substances often contain large numbers of microorganisms, but they do not deteriorate because the microorganisms cannot grow without moisture. An increase in osmotic pressure will adversely affect many microorganisms. The use of salt and sugar aid in preserving food products by exerting an elevated osmotic pressure on the microorganisms that is present. Low temperatures inhibit microorganisms by the physical effects of the temperature and by denying moisture to the microorganisms when the temperature is below freezing. The rate of destruction by high temperatures depends upon the time and temperature, the presence of moisture, the kind of microorganisms present, the number of microorganisms present, and the pH of the medium in which the microorganisms are located.

c. **Chemical Agents.** There are many chemical agents that may inhibit or kill microorganisms. Soap and detergents are important because they will physically remove microorganisms, and they also have an antiseptic action. Alkalies are effective by altering the pH. Alcohol in 70 percent concentration is germicidal. Organic acids, such as acetic and lactic acid, are widely used as antiseptics. Chlorine is the most widely used of all disinfectants. Its efficiency is reduced by the presence of organic materials. Chlorine is added to drinking water in quantities varying from 0.25 to 10 ppm (parts per million). Chlorine is extensively used in dairy plants and other food processing plants to disinfect vats, pipelines, and many other pieces of equipment.

**Continue with Exercises**

**EXERCISES, LESSON 1**

**INSTRUCTIONS.** The following exercises are to be answered by marking the lettered response that best answers the question or by completing the incomplete statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers with the Academy solutions.

1. Match the term in column A with the definition in column B and write your answer in the space provided.

| COLUMN A | | COLUMN B |
|---|---|---|
| ____ Pathogenic. | a. | The study of fungi, including yeasts and molds. |
| ____ Bacteriology. | b. | A mathematical expression of the degree acidity or alkalinity. |
| ____ Microbiology. | c. | The study of the chemical and biological properties of bacteria. |
| ____ Mycology. | d. | A term meaning disease producing. |
| ____ pH. | e. | The study of microscopic organisms, including bacteria, viruses, yeasts, and molds. |

2. List the microorganisms that cause the problems involved in microbiological food spoilage.

   a. _______________.

   b. _______________.

   c. _______________.

3. Microorganisms are both helpful and harmful to man.

   a. True.

   b. False.

4. Which of the following are often found in media for culturing microorganisms?

   a. A nitrogen source.

   b. Yeasts.

   c. Molds.

   d. A source of organic carbon.

   e. Viruses.

   f. Other nutrients.

   g. Inorganic minerals.

   h. Nutrient broth with or without agar.

5. Match the term in column A with the definition in column B and write your answer in the space provided.

| | COLUMN A | | COLUMN B |
|---|---|---|---|
| ____ | Rickettsiae. | a. | Multicellular, consisting of long filaments. |
| ____ | Protozoa. | b. | One-celled microorganisms in various shapes. |
| ____ | Viruses. | c. | Survive only in living cells and require an intermediate host to be transmitted. |
| ____ | Fungi. | d. | Microscopic, unicellular organisms without chlorophyll. |
| ____ | Bacteria | e. | A noncellular, submicroscopic particle of many shapes that lives and reproduces in living cells. |

6. Most of the bacteria of importance in foods range from _____________ in length.

   a. 0.012 to 0.2 micron.

   b. 0.5 to 2.5 microns.

   c. 2 to 10 microns.

   d. 1 to 15 microns.

7. In describing bacteria, we can safely say that most bacteria:

   a. Reproduce multicellular organisms.

   b. Have a distinct nucleus.

   c. Contain chlorophyll.

   d. Are one-celled in structure.

8. A typical cell structure consists of:

   a. A cytoplasmic membrane, a cell wall, and a flagellum.

   b. A cell wall, the cytoplasm, and a nucleus.

   c. A nucleus, a slime layer, and a cytoplasmic membrane.

   d. A capsule, an embryo, and the cytoplasm.

9. The rod-shaped bacteria are called:

   a. Bacilli.

   b. Spirilla.

   c. Cocci.

10. The internal environment of the cell is called the:

    a. Cytoplasm.

    b. Slime.

    c. Capsule.

11. What do we call the long, thread-like filaments attached to some bacterial cells that are used for locomotion?

    a. Spores.

    b. Flagella.

    c. Fungi.

    d. Granules.

12. How do most bacteria reproduce?

    a. Binary fission.

    b. Budding.

    c. Spore formation.

13. Q fever is one of the major milk-borne diseases in this country. Q fever is caused by a:

    a. Mold.

    b. Bacterium.

    c. Virus.

    d. Rickettsia.

    e. Protozoan.

14. Roquefort cheese and Bleu cheese are given their characteristic appearance and flavor by:

    a. Yeasts.

    b. Enzymes.

    c. Molds.

    d. Bacteria.

15. Which of the following can grow at a temperature of 20º F. and a moisture content of 10%?

    a. Enzymes.

    b. Molds.

    c. Yeasts.

16. In relation to their tolerances for extremes of sugar, salt, acid, moisture, and temperature, yeasts occupy a range _______________ those of bacteria and molds.

    a. In between.

    b. Higher than.

    c. Lower than.

17. Select the item below that is an organic catalyst.

    a. Bacteriophage.

    b. Mold.

    c. Yeasts.

    d. Enzyme.

    e. Rickettsia.

18. There are 4 steps in the growth pattern of unicellular bacteria. When the cross wall divides, this action is step number.

a. 4.

b. 3.

c. 2.

d. 1.

19. There are four phases in the growth curve of microorganisms. The period of rapid growth is the __________________ phase.

a. Lag.

b. Stationary.

c. Log.

d. Decline.

20. The period during cell growth in which in which the cells adjust to the new environment with little or no increase in numbers is the ______________ phase.

a. Lag.

b. Decline.

c. Log.

d. Stationary.

21. Prevention or delay of food spoilage is accomplished by lengthening the _______ phase of cell growth.

a. Decline.

b. Log.

c. Stationary.

d. Lag.

22. List the factors that influence microbial growth.

a. ________________________________.

b. ________________________________.

c. ________________________________.

d. ________________________________.

e. ________________________________.

23. Which of the following is/are nutritional requirement(s) of bacteria?

a. Carbohydrates.

b. A source of nitrogen.

c. Vitamins.

d. Water.

e. "a," "b," "c," and "d" above.

24. Bacteria that require the presence of free or atmospheric oxygen for growth are classed as:

a. Aerobic.

b. Anaerobic.

25. In which of the following pH ranges will most bacteria grow and function best?

a. 9.5 to 13.5

b. 6.0 to 8.5.

c. 3.5 to 5.5.

d. 1.5 to 3.5

26. Select the fruit or vegetable that is a low acid (or a non-acid) food?

a. Tomatoes.

b. Apples.

c. Spinach.

d. Lemons.

27. Which of these numbers on the pH scale indicates the highest condition of alkalinity?

a. 2.

b. 5.

c. 9.

d. 12.

28. The growth of <u>Clostridium botulinum</u> is inhibited by increased:

a. Acidity.

b. Alkalinity.

29. Bacterial growth is more easily detected and defined at the ____________ temperature range.

a. Lower.

b. Higher.

30. Most mesophilic bacteria are killed if heated in a liquid medium to 145º F for ____________ minutes.

a. 30.

b. 20.

c. 15.

d. 10.

e. 5.

31. With which class of bacteria is the dairy industry most concerned?

a. Mesophilic.

b. Psychrophilic.

c. Thermophilic.

32. What effect does decreasing the temperature for growing bacteria have on the generation time?

a. Decreases it.

b. Increases it.

c. Has no effect on it.

33. The condition of moisture least conducive to the growth of bacteria is:

a. 70 percent.

b. 50 percent.

c. 30 percent.

d. 15 percent.

34. Which of these require the least amount of water for growth?

    a. Molds.

    b. Yeasts.

    c. Bacteria.

35. What effect do minimum temperatures have on bacteria?

    a. Kill all bacteria.

    b. Kill all harmful bacteria.

    c. Slow bacterial growth.

    d. Damage bacteria so that they will not grow when the temperature is raised.

36. A higher temperature is required to kill bacteria in:

    a. Cream.

    b. Water.

37. Bacteria are usually more resistant to inhibition or destruction when the pH is:

    a. Alkaline.

    b. Optimum for their growth.

    c. Neutral.

    d. Acid.

38. Which varieties of microorganisms are more difficult to kill?

   a. Spores.

   b. Vegetative cells.

   c. Nonencapsulated varieties.

   d. Encapsulated varieties.

   e. Items "a" and "d" above.

39. An agent that checks the growth of microorganisms rather than killing them is known as:

   a. A germicide.

   b. A disinfectant.

   c. A sterilizer.

   d. An antiseptic.

40. The chemical agent most widely used in food processing plants to inhibit or to kill microorganisms is:

   a. Alcohol.

   b. Soap and detergents.

   c. Chlorine.

   d. Organic acids.

   e. Alkalies.

**Check Your Answers on Next Page**

**SOLUTION TO EXERCISES, LESSON 1**

1. d (pathogenic)
   c (bacteriology)
   e (microbiology)
   a (mycology)
   b (pH) (para 1-2)

2. a Bacteria.
   b. Yeasts.
   c. Molds. (para 1-2a)

3. a. True (para 1-3)

4. a. A nitrogen source
   d. A source of organic carbon
   f. Other nutrients
   g. Inorganic minerals
   h. Nutrient broth with or without agar (para 1-3c)

5. c (rickettsiae)
   d (protozoa)
   e (viruses)
   a (fungi)
   b (bacteria) (para 1-5c)

6. c (para 1-6)

7. d (para 1-7a)

8. b (para 1-7a(1))

9. a (para 1-7b)

10. a (para 1-7a(3))

11. b (para 1-7a(5))

12. a (para 1-7d)

13. d (para 1-8)

14. c (para 1-9)

15. b (para 1-9)

16. a (paras 1-9 and 1-10)

17. d (para 1-12)

18. b (para 1-14)

19. c (para 1-16a)

20. a (para 1-16a(1))

21. d (para 1-16b)

22. Nutrition
Oxygen
pH
Temperature
Moisture (para 1-17)

23. e (para 1-17)

24. a (para 1-19)

25. b (paras 1-17 and 1-20b)

26. c (para 1-20)

27. d (para 1-20a)

28. a (para 1-20c)

29. b (para 1-21a(2))

30. d (para 1-22a) Note that for spores of some species "a" may be correct.

31. c (para 1-21b(1))

32. b (para 1-21a(1))

33. d (para 1-24)

34. a (para 1-24)

35. c (para 1-23)

36. a (para 1-22c)

37. b (para 1-26a)

38. e (para 1-26a)

39. d (para 1-26c)

40. c (para 1-26c)

**End of Lesson 1**

## LESSON ASSIGNMENT

**LESSON 2** Food Microbiology.

**LESSON ASSIGNMENT** Paragraphs 2-1 through 2-15.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

2-1. List diseases transmitted to man from the contamination of milk.

2-2. Identify control measures for milk-borne diseases.

2-3. Identify the function of nonpathogenic bacteria in milk products.

2-4. List the tests performed on milk to indicate its quality.

2-5. Identify factors causing undesirable color changes in meats and appropriate preventive measures.

2-6. Identify factors causing ham souring and appropriate preventive measures.

2-7. Identify food poisoning potential in poultry products.

2-8. Identify common infections of shell eggs.

2-9. Identify effective spoilage/control measures used to chill fresh fish.

2-10. Identify tests for spoilage of shellfish and crustaceans by pathogenic organisms.

2-11. List common microorganisms and intestinal diseases transmitted by external contamination of fresh fruits and vegetables.

2-12. Identify the requirements for canning fruits and vegetables, three sources of contamination, and two kinds of swells in canned products.

**SUGGESTION**

After studying the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

# LESSON 2

# FOOD MICROBIOLOGY

## Section I. MICROBIOLOGY OF DAIRY PRODUCTS

### 2-1. INTRODUCTION

a. **General.** It is important to apply the information learned about microbiology in lesson one to food products used by the public. This lesson, Lesson 2, will discuss food microbiology as it is related to dairy products, meats, poultry and shell eggs, waterfoods, fruits, and vegetables.

b. **Milk.** Since milk contains proteins, carbohydrates, fats, vitamins, and minerals, and has a pH of about 6.8, it is little wonder that in addition to being an excellent food for man, it provides an excellent growth medium for microorganisms. Some microorganisms can be harmful while others are beneficial when existing in milk. The beneficial organisms, in most cases, are controlled and used to make other dairy products. Harmful organisms can and must be kept to a minimal, safe level to prevent deterioration, spoilage, and/or disease.

### 2-2. DISEASES FROM MILK

a. **Two Sources of Pathogenic Organisms.** Nonpathogenic bacteria are always found in milk even under the strictest sanitary conditions. However, milk also provides an excellent media for the dissemination of pathogenic microorganisms. Milk may become contaminated with pathogenic organisms anywhere along the line from cow to consumer. This contamination may come from an infected cow or from an infected milk handler. Therefore, we classify the occurrence of pathogenic organisms as coming from two sources.

(1) Organisms that infect the cow and, therefore, the milk.

(2) Organisms causing disease as a result of contamination of the milk by human sources.

b. **Diseases Transmitted From the Cow.** Included in the diseases occurring as a result of organism contamination prior to or at time of lactation (that is, transmitted from the cow) are tuberculosis, brucellosis (undulant fever), streptococcal infections, some staphylococcal infections, and Q fever (rickettsial organisms). (A description of these diseases can be found in any standard medical reference.) Tuberculosis and undulant fever are the most important of these diseases. Both are transmittable from animal to animal or from animal to man. The route from the animal's tissues to the milk is not known for certain, but there is some possibility that Brucella organisms, which cause undulant fever, may be secreted directly from the blood stream into the udder. The infectious agent of bovine tuberculosis is the bacterium Mycobacterium bovis.

There are many species of streptococcal organisms that might be involved with streptococcal infections, such as strep throat and scarlet fever. The infectious agent of Q fever is the rickettsial organism Coxiella burnetii.

c. **Diseases from Handling and Exposure.** Transmission of disease from other than the cow is usually a result of milk contaminated due to handling procedures under conditions of uncleanliness of personnel and equipment, and from exposure of milk to dust or droplets bearing pathogenic microbes. Diseases most commonly transmitted by contamination of milk from this source are: diptheria, typhoid fever, salmonellosis (a common source of blood poisoning), shigellosis (bacillary dysentery), and, again streptococcal infections. (A description of these diseases can be found in any standard medical reference.) The infectious agents of the above diseases are respectively: Corynebacterium diphtheriae, Salmonella typhi, other Salmonella species, Shigella species and Streptococcus species.

## 2-3. CONTROL OF MILK-BORNE DISEASES

a. **Techniques.** Four techniques are employed for the specific control of milk-borne diseases. These are:

(1) The inspection of cattle and elimination of infected animals.

(2) Routine medical examination of all milk handlers and dairy personnel.

(3) The killing of disease agents by the process of pasteurization.

(4) Proper temperature control of milk during storage. This technique serves as a method of lengthening the lag phase of the growth curve of microorganisms.

b. **Pasteurization.** Pasteurization is the process of heating milk to destroy pathogenic microbes. This is followed by rapid cooling. Today, most of us invariably associate pasteurization with milk. However, the process was first devised by Louis Pasteur not for milk, but to destroy the organisms, which could spoil wine. Now, it is important primarily as a means of ensuring safe milk since it destroys all pathogens likely to be present. One of the most difficult disease agents to destroy in milk is the rickettsial agent, Coxiella burnetii, and the cause of Q fever. A drop of even 4ºF (2.2ºC) in the pasteurization temperature will allow some of these organisms to survive. In addition to destroying the pathogens in milk, pasteurization causes a marked decrease in the numbers of nonpathogens, such as Streptococcus lactis and various Lactobacillus species. This enhances the keeping quality of the milk since it is the lactic acid formed by the nonpathogens that is responsible for the souring of milk. Therefore, with fewer organisms, less lactic acid is produced, and the time required for the milk to sour is increased.

(1) Three processes. There are three processes whereby milk may be pasteurized, all of which are effective in eliminating pathogens: vat pasteurization, high-temperature, short time (HTST) pasteurization, and ultra-high-temperature (UHT) pasteurization. Vat pasteurization utilizes a temperature of 145ºF (63ºC) for 30 minutes, whereas the HTST method heats the milk to 161ºF (72ºC) for 15 seconds. Ultra-high-temperature utilizes a temperature of 203º-308ºF (95º-153ºC) for 3 seconds or less. All are followed immediately by rapid cooling.

(2) Importance of sanitary handling. The sanitary handling of milk, along with pasteurization, is most important in preventive medicine. Organisms killed by pasteurization include those of tuberculosis, typhoid fever, bacillary dysentery, diptheria, and scarlet fever. Of course, it is extremely important that the milk not be contaminated after completion of the pasteurization process.

## 2-4. NONPATHOGENIC BACTERIA

### a. Lactic Acid Bacteria.

(1) Bacteria most commonly found in milk. Bacteria invade milk usually as dust-borne contaminants; hence, almost any type may be present. By far the most abundant bacteria making up the normal flora of milk belong to the family Lactobacillaceae. The organisms in this family are frequently referred to as lactic acid bacteria. The members of Lactobacillaceae are nonmotile, anaerobic rods or cocci.

(2) Two groups of lactic acid bacteria. Milk constitutes a typical enrichment culture medium, and so only the most suited types will predominate at any one time. Usually, the first organism to flourish in milk is Streptococcus lactis. These organisms have rather complex nutritional requirements, and all require varying numbers of amino acids and vitamins for growth. In addition, all lactic acid bacteria require a fermentable carbohydrate (lactose) as their source of energy. They ferment the lactose principally to lactic acid. As the pH drops, other species, such as Lactobacillus casei and L. acidophilus may replace Streptococcus lactis as the predominant type. L. casei and L. acidophilus and other lactic acid bacteria will further the fermentation process. Conventionally, these organisms are divided into two groups. Those that essentially produce only lactic acid from fermentable carbohydrates are known as the homofermentative lactic acid bacteria. Those that produce acetic acid, ethanol, and carbon dioxide, as well as lactic acid from a fermentable carbohydrate are called heterofermentative lactic acid bacteria.

**b. Souring and Curd Formation.** Milk, whether raw or pasteurized, will sour on standing due mainly to the production of lactic acid by Streptoccus lactis or by the Lactobacillus species. These organisms do not produce disease in man but ferment the carbohydrate lactose. The bacteria break lactose down into the simple sugar glucose and finally convert glucose to lactic acid, thus lowering the pH of milk (souring). When the pH is lowered from 6.8 to around 4.5, the protein casein in milk becomes insoluble and forms a lumpy precipitate (curd).

(1) Curds and Whey. The liquid portion of milk left after curd formation is termed whey. Curds and whey are often used to make other dairy products under controlled processes. After pasteurization, the lactic acid bacteria are used to ferment the milk. These fermented dairy products—that is, buttermilk, cottage cheese, sour cream, and yogurt--are called cultured dairy products.

(2) Buttermilk and Sour Cream. Cultured buttermilk is made by fermenting skim milk; sour cream, by fermenting milk, followed by separation, consolidation, and conditioning the curd.

## 2-5. PERIODIC TESTS OF MILK

There are various laboratory tests performed on milk to indicate its quality and wholesomeness.

a. **The Phosphatase Test.** A very sensitive, practical method used to determine whether milk has been properly pasteurized is known as the "phosphatase test," which consists of quantitatively determining the activity of the enzyme phosphatase in a sample of milk. Phosphatase itself is an enzyme that is always present in raw milk but is destroyed by the heat if pasteurization is effective. This enzyme is more resistant than any pathogenic bacterium to pasteurization. The test itself, then merely decides if the milk has been heated adequately during the pasteurization process by determining if the enzyme phosphatase has been inactivated.

b. **The Standard Plate Count Test.** The standard-plate count test is given to indicate whether the milk is considered Grade A or not is the standard plate count test. This gives an indication of the approximate number of bacteria in the milk. Obviously, very clean milk will have lower bacterial counts than milk that has been collected or handled under unsanitary conditions. The count is carried out by diluting samples of milk to be tested and mixing the measured quantity with a melted nutrient medium. After incubation, the original counts per milliliter (ml) of milk are determined by multiplying the colony count by the dilution factor. For example, 1 ml of a 1:100 dilution of milk is mixed with a nutrient medium and incubated. If 30 colonies appear on the plate, the standard plate count for the sample of milk is 3,000. In order for milk to be classified as Grade A, the raw milk must not exceed a bacterial growth count of more than 100,000 per milliliter. The same milk after pasteurization cannot exceed a count of over 20,000 per milliliter.

c. **The Coliform Test.** Another important test run of milk is the coliform test. By coliform, we mean the organisms Escherichia coli and Enterobacter aerogenes, both being normal inhabitants of the large intestine. Their presence indicates fecal contamination, possibly from sewage pollution, and the consequent danger of the spread of enteric diseases. These organisms are common sources of acute diarrhea. The laboratory method is quite complex but can be summarized by the following description. Milk is measured into small quantities and inoculated onto media that have indicators for coliform bacteria. Certain substances in the media inhibit the growth of noncoliform bacteria. The sanitary significance of this lies in the fact that the presence of coliform bacteria usually points to unsanitary handling after the completion of the pasteurization process (assuming that the phosphatase test gave evidence of effective pasteurization). In raw milk, the coliform test indicates the degree of contamination, either from careless handling or unsanitary equipment.

## Section II. MICROBIOLOGY OF MEATS

### 2-6. GREEN RING DISCOLORATION

a. **Undesirable Color Changes.** Green ring discoloration and other undesirable color changes are caused by the formation of hydrogen peroxide by certain groups of bacteria. These bacteria will multiply after the meat product has been stuffed into its casing and will cause the discoloration. Meat will normally contain enough of the enzyme catalase to inactivate the hydrogen peroxide produced by bacteria. There are also certain bacteria that produce catalase that will aid in inactivating the hydrogen peroxide. Hydrogen peroxide is produced during the overnight holding period and during the warming period after the meat is removed from the cooler. Killing bacteria in the cooking process does not completely ensure that some sort of discoloration will not occur. The hydrogen peroxide formed before the cooking process is not inactivated by cooking and will continue to exert its action until the product is eventually discolored.

b. **Preventive Measures.** Green ring discoloration may be prevented by one or more of the following measures:

(1) Care in production of trimmings. This would include the length of time the trimmings are held, temperature at which they are held, and the prevention of bacteria inoculation.

(2) Reducing the length of the curing period.

(3) Proper sanitation of stuffers and casings.

(4) Proper tempering procedures.

(5) Control of cooking time and temperature.

(6) Proper control of beef trimmings. Old beef trimmings are a very common source of hydrogen peroxide-producing bacteria and must be inspected very closely if they are to be used in the production of sausage products.

c. **Other Factors.** Green rings may develop in sausage products that have very low bacterial counts and may not develop in those products that have very high counts. This is explained by the fact that bacteria capable of producing hydrogen peroxide must be present, and all groups of bacteria are not capable of producing hydrogen peroxide.

## 2-7. HAM SOURING

a. **Factors Causing Ham Souring.** Ham souring is a complicated condition for which there is no one cause, but instead a group of causes are responsible for this condition. The following factors must be present in order for ham souring to develop:

(1) Portals of entry. Some common examples are agonal (at time of death) invasion, sticking, eviscerating, sawing bones, pumping vessels, and the scalding vat.

(2) Ability of bacteria to grow at curing cellar temperatures. There must be a temperature of 34º to 38ºF (1.11º to 3.33ºC) for twenty to sixty days.

(3) Types of bacteria capable of producing souring. Types of bacteria, which do produce souring, must be present.

(4) Proper oxygen requirements. Proper oxygen requirements for bacteria must be present.

(5) Halophilic characteristic. Bacteria must be halophiles ("salt lovers") or they must be able to adjust to high salt concentrations.

(6) Resistance to nitrate and nitrite. Bacteria must be resistant to nitrate and nitrite.

b. **Preventive Measures.** Some of the effective measures used in preventing ham souring are:

(1) Bacteriologically controlled pickle solution.

(2) Adequate chilling and refrigeration.

(3) Processing of carcass and placement in chill room as rapidly as possible.

(4) Careful sawing of the shank bone.

c. **Characteristics.** Ham souring may develop either in the flesh of the ham or in the bones in the ham and will impart a characteristic putrid odor.

### Section III. MICROBIOLOGY OF POULTRY AND SHELL EGGS

## 2-8. MICROBIOLOGY OF POULTRY

a. **Food Poisoning Potential.** The microbiology of poultry products is similar to that of red meats. The basic principles are the same. Salmonella food poisoning in humans is commonly traced to eating contaminated poultry products. This is a major type of food poisoning.

b. **High Bacterial Counts.** Chicken potpies have been studied extensively by public health officials. The bacterial count in this product is often astoundingly high. The food poisoning potential of this product cannot be dismissed readily. About the same situation exists with regard to stuffed poultry products. Both these products, stuffed poultry and chicken pot pies, need to have considerable work done in lowering their bacterial counts before they can be considered to be completely free of any food poisoning potential.

## 2-9. MICROBIOLOGY OF SHELL EGGS

Shell eggs are attacked by a wide variety of microorganisms. Mold growth on the exterior and interior of shell eggs is often encountered. Moldy eggs result from the infestation of storage facilities with mold spores, and this condition develops more rapidly when there are improper storage conditions that lead to sweating of the eggs. This condition can be prevented by proper sanitation and good storage practices. A wide variety of rots are encountered in shell eggs. They develop most commonly from dirty shells, the washing process, and from bacterial infections in the hens. Inadequate refrigeration will, of course, accelerate the development of rots. Green whites, caused by certain types of feed, are often confused with green rots. Green rots develop in eggs from hens infected with Pseudomonas organisms. Green rots can be differentiated from green whites by the use of an ultraviolet light (black light). The incidence of rots can be reduced by the production of clean eggs and the use of adequate refrigeration.

### Section IV. MICROBIOLOGY OF WATERFOODS

## 2-10. MICROBIOLOGY OF FISH

The flesh of freshly killed healthy fish is usually sterile. (Fish are waterfoods.) The contamination and subsequent spoilage results from the introduction of microorganisms when the fish are dressed. The slime layer and abdominal organs both contain many spoilage organisms, so it is essential that the contamination of the flesh be kept to a minimum. The rate at which spoilage develops can be materially retarded by the use of adequate refrigeration. Ice is still extensively used to refrigerate fish. The use of ice manufactured from potable water (water fit to drink) is essential. Antibiotics and chlorine are now commonly added to ice used to chill fish. The use of these two agents will materially lengthen the storage life of fresh fish.

## 2-11. MICROBIOLOGY OF SHELLFISH AND CRUSTACEANS

Shellfish and crustaceans (also waterfoods) are subject to many types of microbial spoilage. Extensive bacterial spoilage can be detected without any difficulty by organoleptic testing. However, it is impossible to detect the presence of pathogenic organisms organoleptically. Yeast spoilage is not uncommon in oysters that have been handled improperly, and this results in "pink oysters," which are considered to be inedible. Oysters may harbor pathogenic organisms when they are grown in water contaminated by such agents as sewage wastes. It is for this reason that water in which oysters are grown is tested for coliform organisms. The number of coliform organisms serves as an index relative to the contamination of the water. White shrimp are subject to a type of microbial spoilage that results in the development of an inedible "red shrimp." This condition should not be confused with the pink species of shrimp, because a pink color is entirely normal.

# Section V. MICROBIOLOGY OF FRUITS AND VEGETABLES

## 2-12. INTRODUCTION TO FRUITS AND VEGETABLES

a. **Overview.** Fruits and vegetables are considered by many individuals to be of little importance in serving as vehicles for the transmission of pathogenic organisms. Such an assumption, if based entirely on the situation existing in the United States (US), would be partially valid. Even in this country, in spite of our high sanitary standards, fruits and vegetables still are a factor to reckon with in the transmission of intestinal diseases. In many parts of the world, fruits and particularly vegetables are of major importance in disease transmission. This is especially true in those countries maintaining poor sanitary standards. Hunger and epidemics traceable to contaminated plant foods always exist together.

b. **Unsanitary Growing Conditions.** Human fecal material is commonly used as fertilizer in the Orient. Vegetables grow in intimate contact with the soil and are readily contaminated by the organisms of cholera, dysentery, and typhoid fever. The prevalence of these diseases and other intestinal diseases is directly related to the degree with which vegetables are fertilized with human fecal material. Fruits and vegetables are normally processed and distributed under conditions much more unsanitary than is the case with animal origin products. This is particularly true in the Orient, and it is in this part of the world that the greatest opportunity exists for contamination with pathogenic organisms.

c. **Quality Control.** The laxity with which fruits and vegetables are grown, processed, and distributed has never been justified. They have always been, and continue to be, a major factor in disease transmission. A considerable reduction in disease and suffering will be made when fruits and vegetables are eliminated as vehicles for disease transmission. Such an eventuality is not within our sight, so it is essential that all members of the military veterinary service be well versed in the microbiology of fruits and vegetables.

## 2-13. MICROBIOLOGY OF FRUITS

The microorganisms found on fruits may be divided into three different groups. These three groups are spoilage organisms, organisms essential to fermentation, and pathogenic organisms.

a. **Intestinal Diseases.** Of the different groups of diseases, those classified as intestinal diseases are most likely to be transmitted by fruits. The organisms responsible for intestinal diseases are soil and water organisms, so they have an excellent opportunity to contaminate fruits. Fresh fruits are a major cause of concern because they are generally eaten raw and are seldom properly cleaned before they are eaten. Some of the fresh fruits that commonly serve as vehicles for disease transmission are apples, bananas, grapes, lemons, oranges, and peaches. Cholera, dysentery, diarrhea, and typhoid fever are the intestinal diseases most likely to be caused by organisms found on fresh fruits.

b. **External Contamination.** The meat of fruits is generally sterile. The disease-transmission potential of fresh fruits, then, is derived from external contamination. Even a break in the skin of citrus fruits will not result in the meat becoming contaminated because the acid content is high enough to kill most bacteria. Contaminated grapes used in wine production are of little concern because pathogenic organisms are destroyed by the wine. The packaging and packing materials may contaminate fresh fruits. Anthrax spores have been found on hides in which lemons were shipped from Spain to England. It would be entirely possible for any other packaging or packing materials to contaminate fresh fruits. Staphylococcus aureus is a common contaminant of fresh fruits and can readily be introduced to salads. Food poisoning could result if the salad provided a proper medium and the temperature of the salad was in the growth range for Staphylococcus aureus organisms. Contamination of fresh fruits will usually result from direct contact with the soil on the farm; dust on the farm, and from handling at the packing shed or market.

## 2-14. MICROBIOLOGY OF VEGETABLES

a. **External Contamination.** The tissues of vegetables are normally sterile. The problem with contamination is the same as with fruits. External contamination is the only problem worthy of practical consideration. Since the edible portions of vegetables are grown in or near the ground, they are very susceptible to contamination by soil microorganisms. Vegetables are also likely to be contaminated by dust on the farm and contaminated irrigation water. Fresh vegetables are often processed and packed under unsanitary conditions, and they are likely to be contaminated while being processed and packed. Washing vegetables often does little to remove contaminants. In the case of leafy vegetables, washing does more harm than good. In studies conducted on lettuce, it was found that the heads were more thoroughly contaminated following washing than before washing. This is because the outer leaves are more heavily contaminated, and washing distributes the contaminants throughout the head. Human fecal material is used as fertilizer in many parts of the world, and vegetables grown under such conditions present a major problem by serving as vehicles for the transmission of many diseases. We stated above that the tissues of vegetables are sterile; therefore, microbial contamination is a problem only from external contamination.

b. **Two Groups.** The microorganisms of significance found on vegetables may be divided into two basic groups. These groups are spoilage organisms and pathogenic organisms.

c. **Raw Vegetables as a Health Hazard.** The vegetables most likely to be involved in disease transmission are those that are eaten raw. Celery endive, lettuce, onions, parsley, radishes, tomatoes, and watercress are considered as the vegetables presenting the greatest health hazard. Watercress, because of the manner in which it is grown, has the greatest disease-transmission potential of any of the above vegetables. One typhoid epidemic in Philadelphia was traced to the consumption of contaminated watercress at a banquet. Watercress sandwiches were served at this banquet, and eighteen of nineteen people who ate these sandwiches contracted typhoid fever.

d. **Intestinal Disease Organisms.** The intestinal diseases are the most important group of diseases transmitted by fresh vegetables. Intestinal parasites, cholera, dysentery, diarrhea, and typhoid fever are most often involved in the consumption of contaminated fresh vegetables. Typhoid fever is the most important disease contracted from the consumption of contaminated fresh vegetables in the United States. Salmonella typhi, the causative organism of typhoid fever, will remain viable in contaminated soil from twenty-nine to fifty-eight days. This organism is most often introduced into the soil by contaminated irrigation water. In a survey conducted on fresh vegetables in the produce markets in Chicago, coliform organisms were found to be a common contaminant. Escherichia coli organisms were found on 31.5 percent of the fresh vegetables, and 78.3 percent of the fresh vegetables were contaminated with some type of coliform organism. (These microorganisms are a common source of acute diarrhea.) Coliform organisms grow under conditions considered optimum for the typhoid organisms, so if typhoid organisms had been present in the soil in which these vegetables were grown, or any of the workers at the produce markets had been carriers of typhoid, then a large percentage of these vegetables would have undoubtedly been contaminated with typhoid organisms.

## 2-15. MICROBIOLOGY OF CANNED FRUITS AND VEGETABLES

a. **Commercial Sterility.** If all microorganisms in a can of food are destroyed, then the food should keep indefinitely, as far as microorganisms are concerned. Slow chemical changes rather than microorganisms often render canned foods inedible. There are reports of canned food that was edible after 20 to 100 years of storage. It is possible to sterilize any canned food product, but the food might be changed to such an extent that it would be unfit for sale. Food canners, then, don't strive for sterility, but instead settle for "commercial sterility." This entails the destruction of the most resistant organisms normally present that are capable of causing spoilage. The real question is not whether viable bacteria are present, but instead whether the food is wholesome and will keep. Generally speaking, a large number of bacteria are more difficult to kill than a small number. Food products containing a large number of bacteria require higher processing temperatures and longer process times. The types are more important than the total number of bacteria.

b. **Requirements for Canning Acid and Nonacid Foods.** Canned foods are classified as acid and nonacid foods. Acid foods are readily sterilized at 212ºF (100ºC). Nonacid foods must be processed above 212ºF (100ºC). There are a number of nonacid foods such as artichokes, broccoli, brussel sprouts, and mushrooms that are ruined by processing above 212ºF (100ºC). These products are acidified to a point below pH 4.5 by the use of citric acid and the processing temperatures are then lowered. A pH of 4.5 will retard the development of Clostridium botulinum organisms. All of the Clostridium botulinum organisms will not be destroyed in acidified nonacid food, but they are inhibited by a pH below 4.5. The processing of all canned foods, then, is based on the destruction of Clostridium botulinum or the inhibiting of these organisms. As long as Clostridium botulinum organisms are held in a spore state, they are harmless.

c. **Three Sources of Contamination.** Spoilage bacteria and pathogenic bacteria in canned fruits and vegetables are derived from three different sources. These sources are raw fruits and vegetables, canning plant equipment, and ingredients added to canned foods. Fresh fruits and vegetables may contain a heavy bacterial count, and washing and peeling will never remove all of the bacteria. Canning plant equipment will become contaminated by normal processing procedures and must be properly cleaned to prevent undue contamination of the canned product. Ingredients such as sugar added to canned foods may often contribute to high bacterial counts. The canner should assure himself that the bacterial content of these ingredients is within acceptable limits.

d. **Two Kinds of Swells in Cans.** Biological swells and chemical swells are commonly found in canned fruits and vegetables. One or both ends of a can will be distended. This is caused by production of gases.

(1) Biological swells are caused by the production of gases by bacteria. A high storage temperature will materially accelerate the rate of gas production. The average analysis of gases found in biological swells is carbon dioxide, 75 to 97 percent; hydrogen, 0.1 to 5.8 percent; and nitrogen, methane, or oxygen, 1.4 to 20 percent.

(2) Chemical swells are produced as the result of the reaction between acid in the canned foods and the iron in the can. High storage temperature definitely accelerates the rate of gas production in chemical swells. The average analysis of gases found in chemical swells is carbon dioxide, 8.40 percent; hydrogen, 65.50 percent; and nitrogen, 26.10 percent.

**Continue with Exercises**

**EXERCISES, LESSON 2**

**INSTRUCTIONS:** The following exercises are to be answered by marking the lettered response that best answers the question or by completing the incomplete statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers with the Academy solutions.

1. Contamination of milk by pathogenic microorganisms comes from two sources.

   a. Organisms that ________________________________________.

   b. Organisms causing disease as a result of contamination of the milk by

      ____________________________________________

2. List five diseases occurring in man as a result of microorganism contamination at the time of milking. These diseases are milk-borne, from the cow to the consumer.

   a. ____________________________________.

   b. ____________________________________.

   c. ____________________________________.

   d. ____________________________________.

   e. ____________________________________.

3. List five diseases that are transmitted to man as a result of milk being contaminated through careless handling procedures after the milking process.

   a. ____________________________________.

   b. ____________________________________.

   c. ____________________________________.

   d. ____________________________________.

   e. ____________________________________.

4. A number of diseases may be transmitted through milk by an infected cow. All of the following diseases are in this category EXCEPT:

   a. Staphylococcal infections.

   b. Tuberculosis.

   c. Undulant fever.

   d. Salmonellosis.

   e. Q fever.

5. Which of the following are techniques used to control milk-borne diseases?

   a. Medical examination of milk handlers.

   b. Pasteurization.

   c. Temperature control during storage.

   d. Inspection of cows.

   e. "a," "b," "c," and "d" above.

6. Vat pasteurization of milk utilizes a temperature of ______Fahrenheit for _______.

   a. 203º-308º, 3 seconds.

   b. 161º, 15 seconds.

   c. 145º, 30 minutes.

7. The most difficult disease agent to destroy in milk is:

   a. Salmonella typhi.

   b. Coxiella burnetii.

   c. Streptococcus species.

   d. Brucella organisms.

   e. Corynebacterium diphtheriae.

8. When the pH in milk is lowered, as in the production of lactic acid, the milk:

   a. Sours.

   b. Forms lumps.

   c. Sweetens.

   d. Is pasteurized.

9. Which of the following is not a cultured (fermented) dairy product?

   a. Sour cream.

   b. Buttermilk.

   c. Cottage cheese.

   d. Yogurt.

   e. Butter.

10. List three laboratory tests performed on milk which indicate its quality and wholesomeness.

   a. The ______________________________test.

   b. The ______________________________ test.

   c. The ______________________________ test.

11. What laboratory test is used to determine if milk has been properly pasteurized?

    a. The phosphatase test.

    b. The coliform test.

    c. The standard plate count test.

12. Ham souring is caused by halophilic bacteria. These bacteria are:

    a. Sugar lovers.

    b. Salt lovers.

    c. Heat lovers.

    d. Cold lovers.

13. Undesirable color changes in meats are caused by:

    a. Improper cooking time and temperature.

    b. Old beef trimmings.

    c. The length of the curing period.

    d. Hydrogen peroxide.

    e. High bacterial counts.

14. <u>Salmonella</u> microorganisms are a common source of:

    a. Bacillary dysentery.

    b. Typhoid.

    c. Food poisoning.

    d. Q fever.

    e. Strep throat.

15. The bacterial count is often astoundingly high in:

    a. Chicken pot pies.

    b. Fresh fish flesh.

    c. Stuffed poultry products.

    d. Omelettes.

    e. "a" and "c" above.

16. In shell eggs, green rots are caused by:

    a. Storage conditions leading to sweating of the eggs.

    b. Hens infected with Pseudomonas organisms.

    c. Certain types of chicken feed.

17. Ingredients commonly added to the ice used to chill fish are:

    a. Potable water.

    b. Antibiotics.

    c. Chlorine.

    d. "b" and "c" above.

    e. "a," "b," and "c" above.

18. Bacterial spoilage of shellfish and crustaceans can be detected without any difficulty by:

    a. Testing for coliform organisms.

    b. Product color.

    c. Organoleptic testing.

19. "A common contaminant of fresh fruits can readily be introduced to salads." This statement in the text refers to:

    a. Staphylococcus aureus.

    b. Salmonella.

    c. Pseudomonas.

    d. Escherichia coli.

20. Select the vegetable with the greatest disease-transmission potential.

    a. Celery.

    b. Parsley.

    c. Lettuce.

    d. Radishes.

    e. Watercress.

21. "In a survey conducted on fresh vegetables in the produce markets in Chicago, coliform organisms were found to be a common contaminant." Escherichia coli organisms were found on ______________ percent of the fresh vegetables.

    a. 78.3.

    b. 31.5.

22. Broccoli and brussel sprouts are processed for canning:

    a. Above 212ºF.

    b. At 212ºF.

23. Intestinal diseases can be transmitted to people from fresh vegetables. Select the contaminating microorganisms associated with fresh vegetables.

T. Salmonella typhi.

U. Coxiella burnetii.

V. Escherichia coli.

X. Streptococcus lactis.

Y. Clostridium botulinum.

Z. Pseudomonas organisms.

a. U, X, and Z.

b. T, W, and Y.

c. V, Y, and Z.

d. T and V.

e. W and Z.

24. In a spore state, Clostridium botulinum organisms are:

a. Deadly.

b. Harmless.

25. High storage temperatures for canned fruits and vegetables accelerate the rate of biological or chemical gas production. In chemical swells of canned products, the average amount of hydrogen found is:

a. 65.50 percent.

b. 0.1 to 5.8 percent.

**Check Your Answers on Next Page**

**SOLUTIONS TO EXERCISES, LESSON 2**

1. a. Infect the cow
   b. Human sources (para 2-2a)

2. Tuberculosis
   Brucellosis (undulant fever)
   Streptococcal infections
   Staphylococcal infections
   Q fever (rickettsial organisms) (para 2-2b)

3. Diptheria
   Typhoid fever
   Salmonellosis
   Shigellosis
   Streptococcal infections (para 2-2c)

4. d (para 2-2b,c)

5. e (para 2-3a)

6. c (para 2-3b)

7. b (para 2-3b)

8. a (para 2-4b)

9. e (para 2-4b(1))

10. a Phosphatase
    b Standard plate count
    c Coliform (para 2-5)

11. a (para 2-5)

12. b (para 2-7)

13. d (para 2-6)

14. c (para 2-8a)

15. e (para 2-8b)

16. b (para 2-9)

17. d (para 2-10)

18. c (para 2-11)

19. a (para 2-13b)

20. e (para2-14c)

21. b (para 2-14d)

22. a (para 2-15b)

23. d (para 2-14d)

24. b (para 2-15b)

25. a (para 2-15d(2))

**End of Lesson 2**

## LESSON ASSIGNMENT

**LESSON 3** Food Preservation.

**LESSON ASSIGNMENT** Paragraph 3-1 through 3-33.

**LESSON OBJECTIVES** After completing this lesson, you should be able to:

3-1. Identify major causes of food spoilage and principles of food preservation.

3-2. Identify chemical methods use to preserve food, to include salt, sugar, sodium nitrate/sodium nitrite, spices, vinegar, pickling, and fermentation.

3-3. Identify thermal methods used to preserve food, to include smoking, drying, dehydrating, chilling, freezing, canning, freeze dehydration, and irradiation.

3-4. Identify methods used to preserve fruits and vegetables and facts concerning preparation procedures and acceptable disinfection procedures.

3-5. Identify facts concerning legal and illegal uses of food additives and a new method to preserve acid fruits and vegetables.

**SUGGESTION** After studying the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

## FOOD PRESERVATION

### Section I. INTRODUCTION TO PRESERVATION OF FOODS

### 3-1. INTRODUCTION

Plant and animal tissues are ultimately consumed by other organisms. A competition exists between man, other animals, and microorganisms to see who will consume these nutrients first. Because of this competition, man has utilized several methods of food preservation to ensure that he will be the one to consume the nutrients first.

### 3-2. FOOD FIT FOR HUMAN CONSUMPTION

a. **Definition.** The statement "food fit for human consumption" should imply that the food is at the desired stage of development or maturity. It is usually thought of as ripe enough or cured enough to be aesthetically pleasant to eat. In various areas of the United States, people have different ideas as to what is ripe enough or aged enough to eat. However, most of us agree that a ripe tomato is red and that poultry is a tender, young chicken rather than a stewing hen.

b. **Objectionable Changes.** Food must meet certain requirements as far as pollution, contamination, or other objectionable changes are concerned. Food must be free from human contamination, such as night soil (human feces used as fertilizers) on fruits and vegetables, shellfish must not be contaminated by raw sewage, and no contamination can exist from Staphylococcus growth (from skin lesions and oral and nasal cavities of unsanitary food handlers) on red meats. Food should also be free of contamination from insects and rodents that can serve as reservoirs for pathogenic microorganisms. Other forms of contamination include chemical pollution (that is, heavy metals (mercury) latent in fish) and soil-borne contaminants (dirt), which may be heavily laden with bacteria, molds, and so forth.

### 3-3. FOOD SPOILAGE--MICROBIAL ACTION

The two main causes of food spoilage are microbial decomposition and self-decomposition with the help of enzyme action. Food is an excellent nutrient source for microorganisms, nonpathogenic and, sometimes, pathogenic. Pathogenic organisms are an important group that food handlers, processors, inspectors, and consumers are concerned with due to the fact they may cause food poisoning; however, other microorganisms are just as important due to their spoilage potential. Food is spoiled more often by microorganisms than by any other factor. The microorganisms causing spoilage are bacteria, yeasts, and molds. Microorganisms utilize the nutrients from food in order to maintain their life processes and, consequently, cause food spoilage. An example of food spoilage in nature is explained below.

a. **Action of Molds in Apple Decay.** If an apple from a tree falls to the ground, it is bruised in the fall. The microorganisms of the soil are present in billions per spoonful and enter the torn cells caused by the bruise. As the apple juice is slightly acid, most bacteria cannot grow very well in it. But the molds and yeasts can. The molds force their way from one cell to another, building their roadway in new body tissue as they go. They use the sugar from the apple juice to yield energy to build more new tissue. In a few days, they can do an almost complete job of destroying the structure of the apple. Although the apple has but a trace of protein, it is sufficient for the microorganisms.

b. **The Decay Process in Apple.** While the molds have been feasting, yeasts have not been mere bystanders. Almost at once, they dominate the bruise of the apple and ferment the sugars to alcohol. Fruit flies are attracted to this alcohol, and they carry bacteria. Carried to the fermenting tissue, the vinegar bacteria develop and burn up the alcohol. Thus the apple is soon gone, used to make new cells of molds, yeasts, and bacteria. The cellulose that so far remains unchanged is washed by the rain into the surface of the soil. The apple seeds are now free and can possibly propagate to form, in time, a new tree.

c. **The Process in the Soil.** The soil holds the cellulose and, in a few months, cellulose is moved slowly down into the earth where there is little air. Here live a number of important bacteria. Because they don't need air, these bacteria burn up the cellulose and leave acid. This acid is now used by other bacteria, burning it to carbon dioxide and water. The cycle is complete.

d. **The Decay Process in Meat.** With meat, we find that the process of decomposition begins soon after the animal dies. Once dead, the tissue is no longer able to resist the action of microorganisms. If the carcass is not protected, it will be reduced eventually to carbon dioxide, ammonia, hydrogen sulfide, and water in much the same manner as was the apple, but by different organisms.

e. **Optimum Growth Conditions.** These microorganisms are present in the air, in soil, in dust, in water, and we carry them ourselves. All they usually need to start the process is a source of energy; that is, a few drops of juice containing a trace of sugar. If the food is moist and the organisms have humid growing conditions, the invasion is on.

## 3-4. FOOD SPOILAGE--ENZYME ACTION

The action of enzymes, occurring naturally in the cells of food, is also a leading cause in deterioration of food after it has been killed or harvested. Enzymes will naturally diffuse the cells and will chemically combine with other organic compounds or act as catalysts for chemical reactions that will lead to the deterioration of the product (self-deterioration). Complex oxidation-reduction reactions, with enzymes playing primary roles, can lead to such things as rancidity of fats in meats, milk, and other dairy products and putrefaction of meats and browning reactions in meats and vegetables. The process of enzyme action can be either increased or retarded, depending on how the product is handled and treated. Cells can be damaged in numerous ways, which could result in excessive leakage of enzymes; hence, faster deterioration of the product. Various ways of damaging cells are rough handling on the part of personnel, gnawing by insects and rodents, ice crystal puncture due to improper freezing of the product, and cell breakdown due to the action of microorganisms.

a. **Method to Control the Action of Enzymes.** There is no way to completely prevent the leakage of enzymes from cells; therefore, methods have been developed to control the action of enzymes, such as heat treatment (blanching) of some products to inactivate enzymes and the addition of certain chemicals to prevent or retard the oxidation of the product due to enzymes.

b. **Other Types of Spoilage.** The discussion above has suggested other types of spoilage in addition to the two most common types, microbial action and enzyme action. Other types of spoilage are the result of:

(1) Damage by insects and rodents, both direct and indirect (direct by eating or gnawing, and indirect by contaminating with microorganisms).

(2) Chemical changes such as oxidation (rancidity and browning).

(3) Physical changes such as excessive drying (desiccation or freezer burn), wilting of vegetables, and so forth.

## 3-5. PRINCIPLES OF FOOD PRESERVATION

a. **General Spoilage Control.** The damage or spoilage of food products due to microbial and enzyme action can be controlled adequately enough for man to consume a relatively fresh product. Microbial spoilage is controlled by such measures as filtering of liquids to eliminate the bulk of microbes; control of temperature either by heating or cooling to retard the growth of microbes; control of the amount of oxygen by canning, to create an unfavorable environment detrimental to the growth of microbes; addition of chemicals and biological agents, such as nitrates/nitrites, antibiotics, and nonpathogenic microorganisms, to create an environment unfavorable to the growth of pathogenic microorganisms; and the use of very low temperatures, very high temperatures, and radiation to destroy microorganisms.

b. **Spoilage Control by Specific Methods, Programs, and Training.** The prevention of spoilage due to enzymatic action can be and is effectively accomplished through such methods as the application of heat to inactivate enzymes; the addition of antioxidants to prevent or delay the process of oxidation due to enzymes; the establishment of good control programs for elimination of insects and rodents; and through education and supervision of food handlers to prevent physical damage due to rough handling and improper storage of products.

## SECTION II. METHODS OF PRESERVATION--ADDITION OF CHEMICALS

### 3-6. METHODS OF PRESERVATION

The basic methods utilized by the food industry to preserve foods are:

a. Addition of chemicals (food additives).

b. Thermal methods, such as refrigeration, freezing, canning, drying, irradiation,

c. A combination of the above methods.

### 3-7. PRESERVATIVES

The United States Food, Drug, and Cosmetic Act of 1938 contain certain rigid restrictions on the use of certain preservatives. Some of the preservatives that may be legally added to food are sodium benzoate, sulfur dioxide, lactic acid, acetic acid, and sodium nitrate. Some of the preservatives that may not be legally added to food are boric acid, formaldehyde, and salicylic acid. An illegal preservative is one that tends to prevent or retard deterioration, but this would not exclude the use of salt, sugars, vinegars, spices, or substances added to food by direct exposure to wood smoke. A legal preservative must be harmless to health and must not make possible the employment of careless methods or unfit raw materials.

### 3-8. PRESERVATION BY SALT

a. **The Preservative Action of Salt.** Salt is one of our oldest preservatives and is still a widely used preservative. Salt in concentrations in which it is normally used in preservation is not a bactericide, but rather inhibits many species of bacteria. Salt exerts its preservative action by dehydration, direct effect of the chloride ion, removal of oxygen from the medium, sensitization of the organisms to carbon dioxide, and interference with rapid action of proteolytic enzymes.

b. **The Brine Concentration Formula.** The effectiveness of salt is based upon the amount of moisture in the tissues. The ratio of salt to water is expressed as brine concentration. The brine concentration is arrived at by dividing the percentage of salt by the sum of the salt plus the moisture. This figure is then multiplied by 100. Luncheon meat containing 3.5 percent salt and 59 percent moisture would have a brine concentration of 5.60 percent. Let us apply our formula to the foregoing figures:

FORMULA:

$$\frac{\%\ \text{salt}}{\%\ \text{salt} + \%\ \text{moisture}} \times 100 = \text{brine concentration}$$

1st step: $$\frac{3.5\%}{3.5\% + 59\%} \times 100$$

2nd step: $$\frac{.035}{.035 + .59} \times 100$$

3rd step: $$\frac{.035}{.625} \times 100$$

4th step:

```
          .056
.625/ .035000      X      100
        3125
         3750
         3750
```

5th step:

```
.056
 100
05.600 or 5.60%
```

c. **Requirements Vary.** Dried beef containing 50 percent moisture and 3.5 percent salt would have a brine concentration of 6.54 percent. The ratio of salt to total moisture accounts for the relatively small quantities of salt necessary to inhibit bacteria. Thus, cooked pork may require only five percent salt to inhibit the production of toxin by Clostridium botulinum organisms, whereas ten percent salt might be required for the same inhibitory action in dextrose broth. It has been observed that in different media of the same moisture content, there may be more salt required to prevent the formation of Clostridium botulinum toxin in one than in the other. The Clostridium botulinum organism is commonly found in canned meat products and cured meat products. There will normally be sufficient salt present to keep the Clostridium botulinum organisms in a spore-forming state, so that there will be no toxin produced. There must always be sufficient acid or salt to keep the Clostridium botulinum organisms in a spore-forming state.

d. **Salt Loving Organisms.** There is a group of bacteria classified as halophiles ("salt loving") that will grow in the presence of high concentration of salt. Some of these organisms will even grow in a saturated (26 percent) or supersaturated salt solution. Bacteria that will grow in a salt concentration of tenpercent or higher are classified as halophiles. There are also many varieties of yeast and mold that will grow in a salt concentration above ten percent.

## 3-9. PRESERVATION BY SUGAR

The preservative action of sugar, in the concentrations in which it is normally used in meat products, is of minor importance. Sugar is now used mostly for its organoleptic value. Sugar aids in improving the color, flavor, taste, and appearance of meats. Meat cured with sugar will not be as hard, and sugar also aids in acid production, which helps to retard spoilage.

## 3-10. PRESERVATION BY SODIUM NITRATE AND SODIUM NITRITE

Sodium nitrate and sodium nitrite are important curing agents used to establish a pink or red fixed color in cured meat products. This fixed color will remain even after cooling. Sodium nitrate, by a complicated chemical reaction, is reduced to sodium nitrite by the action of muscle tissue and bacteria. In the process of converting nitrate to nitrite, a desirable pink or red fixed color is imparted to the meat. Sodium nitrite is often combined with sodium nitrate. This is done so that if sufficient nitrate is not converted to nitrite to impart a fixed color, there will be enough nitrite present to accomplish this action. Regulations of the Meat and Poultry Inspection Program of the Food Safety and Quality Service, US Department of Agriculture, require not more than a total of 1/4 ounce of nitrite in 100 pounds of chopped meat and/or meat byproducts. These regulations further stipulate that the nitrite content of cured meats may not exceed 125 ppm (parts per million) in the finished products. Nitrates, in addition to being excellent curing agents, also help to inhibit the growth of anaerobic organisms. When nitrate is converted to nitrite, there is some free oxygen liberated, and this free oxygen helps to inhibit the growth of anaerobes. This action is demonstrated by the fact that aerobic bacteria will be found in cured meats and will be found where the atmosphere is normally anaerobic in nature. This proves that free oxygen has been liberated in the process of converting nitrate to nitrite. Most putrefactive bacteria are anaerobic in nature, so the creation of aerobic conditions will inhibit growth of anaerobic bacteria, and, consequently, the spoilage process is slowed down.

## 3-11. PRESERVATION BY SPICES

Spices were used extensively in cured meats before the advent of adequate refrigeration. These spices materially aided in masking taints and off-flavors. The acquired tastes for spices are most pronounced in warm or tropical regions. These areas are in the latitudes where taints and putrefaction occur in the shortest period of time. Many spices are so highly contaminated with microorganisms that they contribute more to spoilage than to preservation. Most meat products containing spices must be heat-treated if they are to have an adequate storage life. To destroy the microorganisms in spices, most are sterilized today by use of ionizing radiation. The use of sterilized spices is now widely practiced in the meat packing industry. Spices are used in cured meats for the following reasons: first, they impart a desirable taste, second, they function as antioxidants, and third, they provide some antimicrobial action. The most commonly used spices, in the descending order of their preservative action, are: mustard, cinnamon, clove, thyme, bay leaves, and allspice.

## 3-12. PRESERVATION BY VINEGAR

The preservative action of vinegar is based upon its acetic acid content. Pathogenic bacteria are rapidly destroyed in pickle solutions containing three percent acetic acid and three and one-half percent salt. Vinegar is important as a preservative, because it reduces the thermal death time of microorganisms and either inhibits or kills microorganisms, depending on the concentration used.

## 3-13. PRESERVATION BY PICKLING AND FERMENTATION

The preservative action of pickling and fermentation is accomplished by utilizing selected microorganisms.

a. **Pickling.** In pickling, salts are combined with selected microorganisms in a pickle solution. The vegetables are preserved and can be kept for a considerable length of time, depending on factors such as temperature. An example of the preservative action of pickling is seen in the difference between fresh cucumbers and the end result, pickles.

b. **Fermentation.** There are two types of fermentation--alcoholic fermentation and acid fermentation. Alcoholic fermentation is used to create alcohol by the anaerobic decomposition of a carbohydrate by yeast to produce ethanol and carbon dioxide. This process is used to produce beer. Acid fermentation is the anaerobic decomposition of a carbohydrate food by microorganisms (or enzymes) to produce the desired flavor and/or a more stable product by lowering the pH. This process is used to produce cheeses and sauerkraut.

# Section III. METHODS OF PRESERVATION--THERMAL METHODS

## 3-14. PRESERVATION BY SMOKING

a. **Desirable Effects of Smoking.** Smoking has been used for several thousand years to preserve meat products. Smoking is rarely used alone any more to preserve meats, but instead is used on cured meats. Some of the desirable effects of smoking cured meats are as follows:

(1) Brings out the color inside cured meats.

(2) Has a drying effect.

(3) Impregnates the outside of the meat with constituents of the smoke that serve as antiseptics and germicides.

(4) Imparts desirable organoleptic properties.

(5) Causes a tenderizing action which results from increased activity of autolytic enzymes if the meat temperature is elevated above 60ºF (16ºC).

(6) Causes a tenderizing action that results from the meat being exposed to high temperatures and high humidities in the smokehouse.

(7) Imparts antioxidants to the fats.

(8) Has a destructive action on microorganisms when the smokehouse temperature is above 120ºF (49ºC).

(9) Imparts a desirable finish or gloss.

(10) Reduces the nitrite content.

b. **Contents of Smoke.** Hardwood smoke will yield the following range of concentration in the smokehouse:

(1) Formaldehyde, 25 to 40 ppm.

(2) Phenols, 20 to 30 ppm.

(3) Formic acid, 90 to 125.

(4) Higher aldehydes, 140 to 180 ppm.

(5) Ketones, 190 to 200 ppm.

(6) Acetic and higher acids, 460 to 500 ppm.

(7) Resins, over 1,000 ppm.

**NOTE:** Of the above constituents, formaldehyde is considered to be one of the chief bactericidal constituents of smoke.

c. **The Incubation Zone.** Mesophilic bacteria will grow during the incubation period or zone, which is 65º to 105ºF (18º to 41ºC). The tendency is for the bacteria count to increase during this period; however, the total count will be considerably reduced at the end of the smoking period. A good smoking practice is not to hold the product in this zone for more than 6 to 8 hours.

d. **The Residual Effect.** The residual effect of the smoke on bacteria is very pronounced. Most smoked cured products will keep considerably longer than unsmoked cured products. The residual effect of smoke against molds is much less than the effect against bacteria.

## 3-15. PRESERVATION BY DRYING

Drying is the loss of moisture. Moisture can be removed from foods by natural drying, evaporation, or dehydration. Reducing the water content of foods concentrates the sugar, salts, and minerals and retards the activity of microorganisms. The drying process is hastened by a greater flow of air over the produce, higher temperatures, a product with porous surfaces, and a product with large surface areas.

a. **Natural Drying.** The natural drying method is used for grains, nuts, spices, legumes such as peas and beans, some fruit and vegetables, and some meats. Food products dried by the sun include raisins, prunes, figs, dates, beans, peas, and jerky. The advantages of sun drying are low equipment cost and no fuel cost. There are some disadvantages, such as a loss of sugar from the food, no control over the temperature, humidity, and air flow, no control over the weather, and some contamination of food from the atmosphere.

b. **Evaporation.** In this method, evaporation, the only variable under control, is the temperature. The method is limited for the most part to milk.

c. **Spray Drying.** Spray drying is used with liquids. The liquid is sent down high-pressure hoses and into a high-pressure nozzle that micronizes the liquid into a superfine mist. The mist enters a sterilized room that has rapid moving, superheated air (400ºF) and settles onto the floor as a powder. Spray drying is utilized to produce milk and powdered eggs.

d. **Drum Drying.** Drum drying is used with heavy liquids. The product is dried on the surface of steam-heated (300ºF) steel drums. Drum drying is utilized to produce tomato paste and purees.

e. **Dehydration.** Dehydration is the most common method used for drying foods. Under this method, temperature, relative humidity, and airflow (air-movement) are all controlled. Atmospheric dehydrators and vacuum dehydrators are used to dry foods. The advantages of the vacuum dehydrator are less oxidation (due to the removal of free oxygen), operation at lower temperatures, and rapid diffusion from cells.

f. **Effects.** Some of the effects of drying, including dehydration, are enumerated below:

(1) Nutrients are concentrated through a reduction of water content in the food.

(2) There is a reduction of water-soluble vitamins such as ascorbic acid, riboflavin, and thiamin.

(3) Proteins may become somewhat denatured because of high temperature used in drying.

(4) Fats may become oxidized and turn rancid. However, the addition of antioxidants aids in the prevention of rancidity.

(5) Carbohydrates may undergo some oxidation, producing a browning reaction. Enzymes involved in this reaction should be inactivated.

(6) When moisture content becomes less than 30 percent, bacteria are retarded. When moisture is less than 6 percent, molds are retarded.

g. **Product Protection.** Foods should be stored in moisture proof containers to prevent dehydration during storage. When foods are put in hermetically sealed containers, nitrogen should be less than 90ºF (32ºC) to prevent deterioration.

## 3-16. EXAMPLE OF DRYING

Most of the dried beef manufactured in this country is made from beef hams. The beef ham is the beef round, which includes the inside, outside, and knuckle cuts of meat. The beef ham is cured in a common commercial pickle and is then dried. After the beef is hung in the smokehouse, it is dried in the following manner: first, steam is turned on for 12 hours to raise the temperature of the meat; second, sawdust fires are then built, and the internal temperature of the meat is maintained at 132ºF (56ºC) for 40 hours; third, the fires are put out, and an internal temperature of 125ºF (52ºC) is maintained for 5 to 10 days by the use of steam coils. After the product is cooled, it is then sliced and packaged in cellophane or glass containers.

a. **Analysis of Dried Beef.** The average analysis of dried beef will be about 52 percent moisture, 10 percent salt, 20 to 50 ppm nitrites, and 0.1 percent nitrate.

b. **Brine Concentration of Dried Beef.** The brine concentration of dried beef will range from 11 to 16 percent.

## 3-17. DEHYDRATING FOODS

Dehydration of foods is a very old process and has had wide application in the preparation of items for the military ration. Charles VI of France, in preparing for the invasion of England in 1386, accumulated large stores of dehydrated food products, including dehydrated egg yolks. Dehydrated food has been used as part of the ration for navies for centuries. General Sherman wrote in his memoirs that during the Atlanta campaign, his army was supplied with desiccated vegetables, concentrated milk, meat, biscuits, and sausage. He stated that his men preferred the simpler and more familiar foods, and they referred to the commissary foods as "desecrated vegetables and consecrated milk!" The American Expeditionary Force, during World War I, used about ten million pounds of dehydrated foods, but they were rather unpopular with our troops. Dehydrated foods were used again during World War II, but, as in World War I, they were not a desirable component of the military ration.

a. **Four Types of Dehydrated Meat Products.** There are four types of meat products dehydrated in this country at the present time. These four types are cooked fresh meat, raw fresh meat, cooked cured meat, and raw cured meat.

b. **Standard for Dehydrated Fresh Meat.** Cooked fresh meat is dehydrated in the largest volume in this country. It is dehydrated to moisture content of about ten percent and is then canned. This product has a pH range of 5.8 to 6.2. Salmonella, Staphylococcus, and Clostridium botulinum organisms will not grow in this product until it is rehydrated.

(1) Moisture content and toxin production. Moisture content is very important in the production of toxin by Clostridium botulinum organisms. Toxin will be produced in 48 hours in meat containing 60 percent moisture and incubated at 98ºF (37ºC). Meat incubated at 98ºF (37ºC) containing 40 percent moisture will have toxin produced in it in 7 days. There will be no toxin produced in meat containing 30 percent moisture. The above information, relative to toxin production by Clostridium botulinum organisms, is based upon samples of meat in which Clostridium botulinum organisms were intentionally introduced in a laboratory experiment.

(2) Mold growth. Mold will grow on dehydrated meat when it is exposed to the atmosphere and is stored at a relative humidity above 75 percent in a temperature range of 50º to 99ºF (10º to 37ºC). Mold growth is not a problem in canned dehydrated meat.

## 3-18. PRESERVATION BY CHILLING

Preservation of meat by chill storage is the most extensively used means of preservation in this country. Chilling prevents the growth of all bacteria except those in the psychrophilic group. The amount of moisture on the surface of the meat and the relative humidity in the cooler are of vital importance to the keeping qualities of the meat. Fresh meat products are stored best at a relative humidity of 85 to 90 percent. Such a humidity range will strike an effective balance between excessive shrinkage and discoloration and microbial growth and slime. While chill storage will retard the growth of all but the psychrophilic group of bacteria, it is not nearly as effective in retarding the growth of yeasts and molds. Mold organisms, particularly, grow well in the chill temperature range and create a real problem in the chill storage of fresh meats. Three factors must be considered in chill storage of subsistence. They are temperature, relative humidity, and air movement.

a. **Temperature.** The chill storage temperature range is from 30º to 50ºF (-1º to 10ºC). Temperature requirements for several items of subsistence are:

(1) Meat--32ºF (0ºC).

(2) Eggs--35ºF (2ºC).

(3) Butter--32º to 34ºF (0º to 1ºC).

(4) Leafy vegetables--35ºF (2ºC).

(5) Root vegetables--50ºF (10ºC).

b. **Relative Humidity.** This is the amount of moisture in the air in relation to the total amount of water vapor that the air can hold at a given temperature. It is expressed in percent. Relative humidity that is higher than optimum humidity results in molding and rotting, which lower than optimum humidity results in wilting and dehydration. Humidity requirements for various items of subsistence are:

(1) Meat--90 percent.

(2) Eggs--88 to 90 percent.

(3) Butter--55 percent.

(4) Leafy vegetables--95 percent.

(5) Root vegetables--85 percent.

(6) Fruits--85 to 90 percent.

c. **Air Movement.** Air movement is especially necessary over fresh fruit and fresh vegetables to dissipate the heat of respiration and the pungent odors. Air movement affects humidity, so it must be controlled. Doubling the velocity of air moving across a product will increase the loss of moisture in the food by one-third.

**3-19. PRESERVATION BY FREEZING**

Freezer storage of meats is practiced largely to equalize the supply of meat available at all seasons of the year. Freezing preserves meat by lowering its temperature below the growth range of most microorganisms, and freezing at 15ºF (-9.4ºC) or lower will deny moisture so that no microorganisms can grow. Bacterial growth will not normally occur below 23ºF (-5ºC). Virtually all-microbial growth (some spores excepted) ceases at 0ºF (-18ºC). Mold growth will not occur below 15ºF (-9.4ºC), because below 15ºF the moisture content is lowered to 6 percent and molds will not grow in 6 percent moisture. See figure 3-1. The figure demonstrates temperature, moisture, and ice relationship. Generally speaking, freezing has no immediate effect on the bacterial count, but there will be a gradual reduction with the passage of time. Lean beef will contain about 70 percent moisture. As the temperature of meat is lowered below its freezing point (beef 29.5ºF (-1.4ºC)), moisture is transformed into ice. A point will be reached at which no microorganisms will grow because there will be an insufficient quantity of free or available moisture. There are two methods of commercial freezing: sharp freezing and quick air freezing. Products to be frozen should be wrapped to prevent dehydration.

a. **Sharp Freezing.** The temperature used in this method is 10ºF (-12ºC), which freezes the product solid in 3 to 72 hours. The process results in large ice crystal formation, which will rupture cell membranes, cause enzyme leakage, and hasten self-decomposition. This is not the method of choice.

b. **Quick Freezing.** This is the air blast method and uses forced air at a temperature of -40ºF (-40ºC), which freezes the product solid in about 30 minutes. (Note that -40ºF and -40ºC is the only point in the two temperature scales where the scales have the same numerical value.) This method results in small ice crystal formation with minimum cell membrane rupture and the food thaws to a more natural state. This is the method of choice and is widely used in industry.

| | DEGREES | | ICE | | MOISTURE |
|---|---|---|---|---|---|
| At: | 29.0ºF (-1.5ºC) | there is | 35% | and | 65% |
| At: | 28.0ºF (-2.2ºC) | there is | 55% | and | 45% |
| At: | 26.0ºF (-3.3ºC) | there is | 70% | and | 30% |
| At: | 23.0ºF (-5.0ºC) | there is | 82% | and | 18% |
| At: | 19.0ºF (-7.2ºC) | there is | 88% | and | 12% |
| At: | 14.0ºF (-10.0ºC) | there is | 94% | and | 6% |
| At: | 0ºF (-17.8ºC) | there is | 96% | and | 4% |
| At: | -5.0ºF (-20.6ºC) | there is | 98% | and | 2% |

BASED UPON BEEF CONTAINING 70% FREE MOISTURE WITH A FREEZING POINT OF 29.5ºF (-1.4ºC).

Figure 3-1. Temperature, ice, free moisture relationship.

## 3-20. PRESERVATION BY CANNING

a. **Two Types of Canned Meats.** There are two general types of canned meats relative to their storage temperature requirements. These two types of canned meats are: shelf-stable meats and cured meats requiring storage temperatures below 50ºF (10ºC), with best storage conditions being in a range of 32º to 40ºF (0º to 4ºC).

b. **Four Groups of Spoilage Microorganisms.** There are four groups of spoilage microorganisms in canned meats, based upon their reactions to heat, salt, and pH:

(1) Nonsporeforming microorganisms killed at relatively low temperatures. This includes nonsporeforming bacteria, yeasts, and molds.

(2) Genus Bacillus--forms spores but is not as heat resistant as Clostridium organisms. Bacillus organisms must be killed by heat, because they have a high salt tolerance.

(3) Clostridium organisms--have a high resistance to heat and must be either killed by heat or held in a dormant spore state by salt, acidity, or heat injury.

(4) Thermoduric organisms--are not ordinarily killed by canning temperatures, but are held dormant by 5 percent brine concentration.

**NOTE:** Each canned meat product is a law unto itself, and it must be processed according to the cumulative effects of heat, salt, and pH on the microorganisms normally present. The combined effects of heat and brine concentration on Clostridium spores are the basis of the canned cured meat industry in the United States.

c. **Swells in Canned Meats.** Canned meats are subject to spoilage, which is classified as biological swells and chemical swells. Biological swells are caused by the production of carbon dioxide by bacteria. Chemical swells are not common in canned meats. This is because meats are not highly acid, and chemical swells are caused by the action of acid on the iron in the can, with the resulting production of hydrogen gas.

## 3-21. FREEZE DEHYDRATION

Freeze-dehydrated foods are expensive items, but they are easy to store and will keep in storage indefinitely. They are being used more extensively by the military at the present time. By way of introducing the discussion of freeze dehydration, we say that the three states of matter are solid, liquid, and gas. When ice is heated, it changes to water, and then to vapor, or from a solid to a liquid to a gas. When a solid changes to a gaseous state without passing through the liquid state, we call it sublimation. A good example of sublimation at atmospheric pressure is dry ice changing to the gaseous state. Sublimation is the basic physical process underlying freeze dehydration. Ice formed in the frozen food product is converted under vacuum to vapor and removed from the food without passing through the liquid state. Atmospheric pressure at sea level is 760 mm of mercury per inch. Sublimating ice in foods to vapor without the intervening liquid phase requires reducing atmospheric pressure to below 4.6 mm of mercury per inch and applying heat. Vacuum is required to reduce the atmospheric pressure in this case.

a. **Removal of Moisture.** In the application of the process to freeze dehydration of foods, food is frozen in thin layers so that a greater surface area is exposed. The frozen food is placed in the vacuum chamber of a sublimator where a vacuum is drawn and pressure is lowered to 1 mm of mercury per inch or lower. Heat is applied, ice crystals are changed to vapor, and the vapor passes from the food by diffusion. The removed vapor is returned to atmospheric pressure and eliminated as water. Freeze-dehydrated products require protection, since they tend to absorb moisture and oxygen from the air, because there is a higher concentration of moisture in the atmosphere than in the food product.

b. **In a Processing Plant.** The freeze dehydration process in a plant proceeds as follows: a frozen product is received at the plant from the original processor and is stored until ready for use. When the product is to be processed, it is spread thinly on trays to provide the greatest surface area for evaporation, and the trays are placed on carts. The loaded carts are placed in a freezer at 20ºF (-7ºC). To begin the sublimation process, the frozen product on trays is placed in sublimator cabinets that are then sealed and placed in a chamber where the internal pressure is reduced to 0.5 mm of mercury per inch by drawing a vacuum. When the frozen product is at a sufficiently low pressure, heat is applied through coils underneath the trays to change the ice within the food to a vapor. The vapor is removed. When the process is considered complete, the vacuum is broken by injecting nitrogen into the chamber. Nitrogen is used to prevent oxygen from entering and combining with the product, which could cause oxidative rancidity. If the moisture content is low enough, the trays are removed from the cabinets. The moisture content should be about two percent.

c. **Packaging Requirement.** Freeze-dehydrated products are extremely reactive to oxygen and moisture and must be protected from them to remain good. Proper packaging is required. The primary requirement during packaging is to prevent absorption of moisture and oxygen from the air. To accomplish this, the product is transported through an airlock to the humidity-controlled packaging room. The product is carefully weighed and placed in cans. A lid is placed on each and is crimped in place but not yet sealed. The cans are placed in a vacuum chamber. A vacuum is drawn to remove the oxygen. Nitrogen is introduced to replace the oxygen. The cans are then removed from the chamber, inspected for vacuum by the sound of a tap on the lid, and the can lids are sealed.

## 3-22. PRESERVATION BY RADIATION

a. **Effect of Radiation on Foods.** The preservation of foods by the use of ionizing radiation is a relatively new means of preservation. The food is preserved because the quick dose of radiation destroys all microorganisms, including bacteria, destroys insects in all life cycle stages, inhibits sprouting on vegetables, and prevents some chemical (enzymatic) deterioration. The dosage will not inactivate all enzymes, and spoilage from enzymatic activity is a major problem in irradiated foods. After irradiation, the products are normally placed in hermetically sealed containers to keep out contaminating microorganisms.

b. **Sources and Dosage of Radiation.** The sources of ionizing radiation used are gamma radiation, such as cobalt 60, beta radiation, electron beam, and x-ray beam. The radiation source is held a few centimeters from the product. A dosage of 2.5 to 5 million rad is required to kill all bacteria.

## Section IV. PRESERVATION OF FRUITS AND VEGETABLES

### 3-23. PRESERVATION OF FRUITS

a. **Sugar as a Preservative.** Fruits may be preserved by many of the methods employed for preserving foods of animal origin. Sugar is commonly used to preserve many fruits. The minimum concentration of sugar that will effectively serve as a preservative is 25 percent. The heat treatment, the fruit is subjected to and the acidity of the product will both have a direct bearing on the amount of sugar required. In the case of jams, jellies, and preserves, 45 percent sugar and an acidity of 0.8 percent will not be adequate as a preservative. With the combination of 45 percent sugar and 1.2 percent acidity, jam, jellies, and preserves will be adequately preserved.

b. **Drying of Fruits.** Drying has been used for many centuries to preserve fruits. Bacteria, yeasts, and molds are commonly found on dried fruits. It is uncommon to find sterile dried fruits. The total microbial count will usually be less than 10,000 organisms per gram, and this count will gradually decrease if the moisture content remains low. Souring in dried fruits results from the growth of yeasts. Dried fruits will generally have microbial counts much lower than the count in dried vegetables.

c. **Pasteurization.** Preservation by pasteurization is a relatively new process and is used more on dates than on any other kind of fruit. Following pasteurization, the number of microorganisms will be reduced by as much as 93 to 99 percent. Large, commercial, continuous pasteurizers are used and are capable of processing several thousand cases daily. The pasteurization temperatures will vary from 160º to 180ºF (71º to 82ºC). Dates are held in this temperature range from 30 to 90 minutes, and the humidity will vary from 70 to 100 percent.

d. **Sulfur Dioxide.** Sulfur dioxide has been used for many years in the preservation of dried and fresh fruits. Sulfur dioxide is of definite value in preserving the color of dried fruits. Sulfur dioxide has a minor bacteriostatic action against bacteria, yeasts, and molds. Yeasts are more sensitive to sulfur dioxide than bacteria and molds. Sulfur dioxide will delay the rate of deterioration in storage grapes by as much as 50 percent.

e. **Freezing.** Fruits are frozen to equalize the supply available during all seasons of the year. The preservation principles are the same as with foods of animal origin. Freezing preserves fruits by lowering the temperature below the growth range of microorganisms and by converting available moisture to ice. A temperature of 0ºF (-18ºC) or lower is desirable for freezing and storing frozen fruits. Freezing will have little immediate effect on the microbial content, but there will be a gradual reduction in numbers during storage. The treatments given to fruits in preparation for freezing, such as blanching and the addition of sugar, are usually for the purpose of preventing oxidation or enzyme activity. Enzyme activity is one of the important causes of deterioration of fruits during freezing and thawing.

f. **Additives Used Before Freezing.** The most common treatment given to fruits in preparation for freezing is the addition of sugar or sugar syrup. Sugar protects the fruit from air and also slows up enzyme activity. The amount of sugar used will generally vary from 20 to 50 percent. Sulfur dioxide or vitamin C is often added to fruits prior to freezing to preserve their natural color.

## 3-24. PRESERVATION OF VEGETABLES

a. **Moisture Content and Microbial Count.** Vegetables are preserved by dehydration by reducing the water content to such a point that bacteriological and chemical changes are prevented. The moisture content of dehydrated vegetables will vary from 5 to 20 percent. The average moisture content will be about ten percent. Dehydrated vegetables with low sugar content will have moisture content of five to ten percent. Those vegetables having high sugar content will have moisture content of 15 to 20 percent when dehydrated. Many dehydrated vegetables will have a total microbial count in excess of 500,000 organisms per gram. Yeasts are uncommon on dehydrated vegetables. Molds are commonly found on dehydrated vegetables, but they are not as common as bacteria. The total microbial count will gradually reduce with age. The number of microorganisms on dried fruits is much smaller than the number on dehydrated vegetables.

b. **Preparing Vegetables for Freezing.** Frozen vegetables will normally have a much higher microbial count than frozen fruits. A temperature of 0ºF (-18ºC) or less is desirable for freezing and storing vegetables. All vegetables must be blanched prior to freezing. Blanching is carried out to inactivate enzymes and is accomplished at a temperature of 194ºF to 212ºF (90º to 100ºC) for one to five minutes. Steam or hot water may be used for blanching. A desirable bacterial content in the finished product is less than 80,000 organisms per gram. Vegetables with such a count are considered to have been properly processed. Proper processing includes the following steps:

(1) Blanching at a high enough temperature to destroy all surface bacteria except spore forming bacteria.

(2) Cooling rapidly in potable water following blanching.

(3) Proper handling before and after freezing.

## 3-25. ACCEPTABLE DISINFECTION PROCEDURES FOR FRUITS AND VEGETABLES

Fresh fruits and vegetables grown in areas where human fecal material is used as a fertilizer and/or where gastrointestinal or parasitic diseases may be expected to be prevalent are NOT consumed raw except on the approval of the surgeon. Where vegetables are grown in areas fertilized with human fecal material, no leafy vegetables are served raw except with the approval of the surgeon, in which case they are cleaned and disinfected in the same manner as prescribed for hard-skinned fruits and vegetables. Hard-skinned fruits and vegetables with intact surfaces may be used if necessary after disinfection has been carried out as described in a and b:

a. Thoroughly wash in clean, potable water.

b. Disinfect by either method described in paragraph (1) or (2) below:

(1) Immerse in water at 160ºF (71ºC) for 1 minute, or

(2) Accomplish chemical disinfection as follows:

(a) Wash thoroughly in a chlorine solution made by dissolving one package of Disinfectant, Chlorine, Food Service, in 20 gallons of warm water, 100ºF (38ºC).

(b) Completely immerse for 30 minutes in a separately prepared solution made by dissolving one package of Disinfectant, Chlorine, Food Service, in 20 gallons of warm water, 100ºF (38ºC). Stir occasionally to obtain thorough wetting of vegetables or fruits surface.

(c) Remove vegetables or fruits after 30 minutes and rinse thoroughly in potable water. Do not use solutions of chlorine more than once.

## Section V. FOOD ADDITIVES

### 3-26. INTRODUCTION

A food additive is a nonnutritive substance added intentionally to food, generally in small quantities, to improve its appearance, flavor, texture, or storage properties. It also may be defined as a substance or a mixture of substances, other than a basic foodstuff, which is present in a food resulting from any aspect of production, processing, storage, or packaging. The term does not include chance contaminants. Responsibility for control of food additives in the US is with the Food and Drug Administration (FDA).

### 3-27. REQUIREMENTS FOR APPROVAL

The FDA has developed certain requirements for approval of a substance as a food additive. In the case of nonapproved substances, approval by the FDA is granted upon submission of scientific data clearly showing that the intended chemical is harmless in the intended food application at the intended level of use or consumption. This is done by petition to the FDA. The FDA then sets limits with respect to the kinds of foods in which the additive may be used and the maximum concentration that may be employed. Commonly, a food additive may be permitted at a level of 100 ppm in one food, only 25 ppm in another food, and may be prohibited from use in a third food. At present, over 2,400 food additives may be used in foods within the limits that have been deemed safe by the FDA. In addition to listing newly approved additives, the FDA removes from the listing those additives whose safety is in doubt due to new data. All changes in food additive status are published in the Federal Register.

**3-28. BURDEN OF PROOF**

The burden of proof concerning the safety of food additives now lies with the organization that wants to use or market the additive. Prior to 1958, the burden was on the FDA that had to prove that substances were unsafe before preventing their use. This often took several years and was expensive to the government. Data to support the safe use of an additive usually requires at least 2 years of feeding tests on two species of animals. This normally runs into a cost of several thousands of dollars. The FDA requires that additives appear on the labels of foods.

**3-29. LEGITIMATE USES**

Some legitimate uses of food additives are to:

a. Maintain the nutritional quality of food.

b. Enhance the keeping quality or stability of foods with resulting reduction in food losses.

c. Make food attractive to the consumer in a manner that does not lead to deception.

d. Provide essential aids in food processing.

**3-30. ILLEGAL USES**

Some of the illegal uses of chemical additives are:

a. Addition of borates in codfish and whole eggs to mask poor manufacturing or inadequate storage.

b. Use of chrome yellow on coffee beans to make them appear to be of better quality.

c. Use of copper on canned peas to make the peas appear younger in coloration.

d. Addition of fluorine compounds in lieu of pasteurizing in beer and wine to stop fermentation.

e. Addition of formaldehyde in milk to kill bacteria or in frozen eggs to conceal the odor of decomposition.

f. Use of hydrogen peroxide as a preservative in cream and milk.

g. Use of salicylates in shrimp sauce to delay decomposition.

h. Use of sodium nitrate in fish fillets to prevent spoilage.

i. Use of sulfites to redden stale meat.

## Section VI. ASEPTIC STORAGE SYSTEM FOR CANNING

### 3-31. IMPROVED PRESERVATION OF ACID FRUITS AND VEGETABLES

Two researchers from Purdue University developed and are continuing to improve a method for the processing and storage of fruits and vegetables that virtually eliminates spoilage of acid fruits and vegetables for long periods of time. The process is now being used commercially in the US and Japan. The USDA has shown its interest by having had a number of studies done. One USDA specialist stated that the system represents a major technological breakthrough, especially if it is extended to a wide variety of products. Currently, the system applies primarily to tomatoes, but it also has been applied to chopped and pureed fruits and vegetables. Work is being done with applesauce, apple juice, pears, cranberries, and grapes. The researchers believe that the system can be developed to include diced and chunk foods like corn and beans.

### 3-32. POTENTIAL USE BY THE CANNING INDUSTRY

The system was developed initially to extend the short canning season. One researcher explained that 80 percent of our tomatoes are grown in California and that 75 percent of those are consumed east of the Mississippi River. Now, tomato products are processed in California, put into cans or barrels, and shipped to users who must open the containers and dispose of them before using the product. Under the new system, large users will be able to order a fresher product by the thousands of gallons. The canning industry east of the Mississippi may be reestablished as a consequence. This development may result in:

a. Boosting the export of US tomatoes alone by $500 million.

b. Saving of metal and glass now used in small shipment units.

c. Saving wasted fruit and vegetables at harvest time.

d. Increasing crop sizes.

e. Reducing processing and shipping costs.

f. Helping small food processors compete with the food giants.

## 3-33. DESCRIPTION OF PROCESSING AND STORAGE SYSTEM

The preservation method is based on an aseptic storage system. Storage tanks are presterilized by a special system and put under pressure with nitrogen to keep out air. The challenge involved development of commercially feasible equipment that eliminated all bacterial organisms, enzymes, and oxygen from tomato processing and storage. Research involved scaling up three times before commercial size was achieved. The process does not change the nutritional quality, color, or flavor of the product. In Japan, a plant has been constructed to process and store tomatoes with this system.

**Continue with Exercises**

**EXERCISES, LESSON 3**

**REQUIREMENT.** The following exercises are to be answered by marking the lettered response that best answers the question or by completing the incomplete statement or by writing the answers to the question or by completing the incomplete statement or by writing the answer in the space provided at the end of the question.

After you have completed all the exercises, turn to "Solutions to Exercises, Lesson 3" at the end of the lesson and check your answers with the approved solutions.

1. Which of the following are considered the <u>two</u> most important causes of food spoilage?

   a. Chemical changes.

   b. Enzyme action.

   c. Insects and rodents.

   d. Physical changes.

   e. Microbial activity.

2. Food deterioration is caused by microorganisms using the nutrients from food to maintain their life processes.

   a. True.

   b. False.

3. "Food fit for human consumption" meets the requirement of being free from contamination by:

   a. Night soil.

   b. Raw sewage.

   c. Chemical pollution.

   d. Insects and rodents.

   e. "a," "b," "c," and "d" above.

4. Apple juice is slightly acid. Microorganisms that grow well in apples are:

   a. Molds.

   b. Bacteria.

   c. Yeasts.

   d. "a" and "c" above.

   e. "a," "b," and "c" above.

5. Enzyme action can result in:

   a. Rotting of meats.

   b. Rancidity of fats, milk, and butter.

   c. Browning reactions in meats and vegetables.

   d. "a," "b," and "c" above.

6. Heat treatment (blanching) of some products is used to inactivate:

   a. Bacteria.

   b. Enzymes.

   c. Yeasts.

   d. Molds.

7. Select <u>four</u> general measures used in food preservation to control microbial spoilage in food.

   a. Addition of antioxidants.

   b. Control of pH of the product.

   c. Addition of chemical and biological agents.

   d. Control of amount of oxygen in the food environment.

   e. Control of insects and rodents.

   f. Prevention of rough handling and improper storage.

   g. Control of temperature.

8. From the list of control measures given in exercise number seven, select <u>three</u> that are applicable to the control of enzymatic action that can cause food spoilage.

   a. ______________________________.

   b. ______________________________.

   c. ______________________________.

9. List at least six methods of preserving foods on a commercial basis.

   a. ______________________________.

   b. ______________________________.

   c. ______________________________.

   d. ______________________________.

   e. ______________________________.

   f. ______________________________.

10. A preservative that may NOT be legally added to food is:

    a. Salicylic acid.

    b. Acetic acid.

    c. Sodium benzoate.

    d. Sulfur dioxide.

    e. Sodium nitrite.

11. A widely-used preservative inhibits many species of bacteria by dehydration and interference with rapid action by proteolytic enzymes. This preservative is:

    a. Sugar.

    b. Sodium nitrate.

    c. Salt.

    d. Spices.

    e. Vinegar.

12. If cooked pork requires five percent salt to inhibit production of toxin by bacteria and 59 percent moisture, what is the required brine concentration? (Use the formula in the text.)

a. 8.3 percent.

b. 8.0 percent.

c. 7.9 percent.

d. 7.8 percent.

e. 7.7 percent.

13. Bacteria that grow in ten percent salt concentration are:

a. Thermophiles.

b. Halophiles.

c. Psychrophiles.

d. Mesophiles.

14. Sodium nitrate and sodium nitrite are used to:

a. Establish a fixed pink or red color in cured meat products.

b. Inhibit the growth of anaerobic (putrefactive) bacteria.

c. Aid in acid production.

d. "a," "b," and "c" above.

e. "a" and "b" above.

15. The use of sterilized spices is widely practiced in the meat packing industry. Select the spice that has the most preservative action.

    a. Bay leaves.

    b. Cloves.

    c. Cinnamon.

    d. Thyme.

    e. Allspice.

16. Pathogenic bacteria are rapidly destroyed by a solution of three percent acetic acid and three and one-half percent salt. This method of preservation refers to:

    a. Vinegar.

    b. Spices.

    c. Sugar.

    d. Sodium nitrate.

    e. Brine concentration.

17. From the following list of effects, select the desirable effects caused by smoking cured meats, as described in the lesson.

    a. Imparts organoleptic properties.

    b. Rapidly destroys pathogenic bacteria.

    c. Increases the tenderizing action of autolytic enzymes.

    d. Masks taints and off-flavors.

    e. Reduces the nitrite content.

    f. Imparts antioxidants to the fat.

    g. Aids in acid production.

18. Of the constituents of hardwood smoke, select the one considered to have the most bactericidal effect.

    a. Ketones.

    b. Formaldehyde.

    c. Resins.

    d. Acetic and higher acids.

    e. Higher aldehydes.

19. List three methods of drying food with no freezing involved.

    a. ____________________________________________.

    b. ____________________________________________.

    c. ____________________________________________.

20. List three variables that may be controlled when foods are dehydrated or when they are in chill storage.

    a. ____________________________________________.

    b. ____________________________________________.

    c. ____________________________________________.

21. From the following list of effects, select the preservative effects of drying.

    a. Nutrients are concentrated.

    b. Color of product is enhanced.

    c. A reduction of water-soluble vitamins occurs.

    d. Oxidation of carbohydrates, producing a browning reaction.

    e. A tenderizing action is produced.

    f. Proteins may become somewhat denatured.

    g. Fats may become oxidized.

22. When dried foods are put in moisture-proof containers, ___________ is added to prevent oxidation.

    a. Sugar.

    b. Sodium nitrite.

    c. Phenol.

    d. Acetic acid.

    e. Nitrogen.

23. When beef is dried, the internal temperature is maintained at ____________ Fahrenheit for 40 hours.

    a. 132º.

    b. 125º.

    c. 90º.

24. Cooked fresh meat for canning is dehydrated to a moisture content of about:

    a. 75 percent.

    b. 52 percent.

    c. 40 percent.

    d. 10 percent.

    e. 6 percent.

25. Mold will grow on dehydrated meat when it is stored in relative humidity above _________ percent, in a temperature range of _________________ Fahrenheit.

    a. 60; 45º to 90º.

    b. 75; 50º to 99º.

    c. 85; 60º to 104º.

26. _______________ grow particularly well in the chill temperature range and create a real problem in the chill storage of fresh meats.

a. Yeasts.

b. Enzymes.

c. Molds.

27. Bacteria in the _______________group are least affected in the process of chilling meats.

a. Psychrophilic.

b. Mesophilic.

c. Thermophilic.

d. Microphilic.

28. The chill storage temperature requirement for leafy vegetables is Fahrenheit.

a. 32º

b. 50º

c. 34º

d. 40º

e. 35º

29. The humidity requirement for fruits is_________________percent.

a. 95

b. 88 to 90

c. 90

d. 85 to 90

e. 85

30. Relative humidity higher than optimum results in ______________________________.

31. Relative humidity lower than optimum results in _______________________________.

32. Meats can be preserved by storing them at a temperature of ________________ or lower so that no microorganisms can grow.

    a. 29.5ºF (-1.4ºC)

    b. 27ºF (-3ºC)

    c. 23ºF (-5ºC)

    d. 15ºF (-9.4ºC)

33. The___________________ freezing method results in food thawing to a more natural state.

    a. Quick

    b. Sharp

34. In the quick freezing method, at 0º Fahrenheit, the percentage of ice is ____________ and the percentage of moisture is ______.

    a. 98%; 2 percent

    b. 94%; 6 percent

    c. 96%; 4 percent.

    d. 88%; 12 percent.

    e. 82%; 18 percent.

35. Production of carbon dioxide in canned meat products is the cause of:

    a. Chemical swells

    b. Biological swells

36. Canning temperatures will ordinarily kill all spoilage microorganisms EXCEPT:

a. Nonsporeforming yeasts

b. Clostridium organisms

c. Bacillus organisms

d. Thermoduric organisms

37. The basic physical process underlying freeze dehydration is sublimation. In sublimation, a solid changes to a ______________ state without passing through the __________________ state. A good example of sublimation is _________________________ .

38. The moisture content of a freeze-dehydrated product should be about _______.

39. Proper packaging is required for freeze-dehydrated products to prevent ____________________________.

40. The ionizing radiation dosage required to kill all bacteria, insects, and to inhibit sprouting on vegetables is:_______________________________________ .

41. For jams, jellies, and preserves, an adequate preservative is a combination of _________ percent sugar and _________ percent acidity.

a. 45; 1.2.

b. 46; 0.8.

c. 25; 2.0.

42. Preservation by pasteurization is used extensively on which of these fruits?

a. Apricots.

b. Cranberries.

c. Dates.

d. Raisins.

43. Which of these is most commonly used to preserve fruits?

  a. Honey.

  b. Salt.

  c. Sodium nitrate and sodium nitrite.

  d. Sugar.

44. The additive used to delay the rate of deterioration of storage grapes is:

  a. Sugar.

  b. Chlorine.

  c. Sulfur dioxide.

  d. Yeasts.

  e. Nitrogen.

45. The number of microorganisms on dried fruit is much smaller than the number on dehydrated vegetables.

  a. True.

  b. False.

46. Many dehydrated vegetables have a total microbial count in excess of organisms per gram.

  a. 350,000.

  b. 80,000.

  c. 600,000.

  d. 160,000.

  e. 500,000.

47. Blanching of vegetables prior to freezing is accomplished at a temperature of ______Fahrenheit for_________ minutes.

a. 160º; 1 1/2.

b. 194º to 212º; 5.

c. 100º; 30.

48. Where gastrointestinal or parasitical diseases may be expected, chemical disinfection of hard-skinned fruits and vegetables is accomplished with a solution of chlorine in warm water (100ºF), immersing them completely for ____ minutes.

a. 30.

b. 20.

c. 5.

49. The Food and Drug Administration (FDA) lists 2,400 food additives which may be used in foods. All changes in food additives status are published in the: ____________________________________________________________.

50. Data to support the safe use of an additive usually requires at least 2 years of feeding tests on two species of animals. The burden of proof concerning the safety of food additives lies with:

____________________________________________________________

____________________________________________________________.

51. From the statements that are listed, select legitimate uses of food additives.

a. Adding fluorine compounds to stop fermentation of beer and wine.

b. Maintaining the nutritional quality of foods.

c. Enhancing the keeping quality or stability of food.

d. Using sodium nitrate in fish fillets to prevent spoilage.

e. Adding borates to fish or eggs to enhance color.

f. Making food attractive to the consumer.

g. Adding formaldehyde to milk to kill bacteria.

h. Providing essential aids in food processing.

52. List two illegal uses of chemical additives given in the text.

a. ______________________________________________________________

______________________________________________________________.

b. ______________________________________________________________

______________________________________________________________.

**Check Your Answers on Next Page**

**SOLUTIONS TO EXERCISES, LESSON 3**

1. b,e (para 3-3)

2. a (para 3-3)

3. e (para 3-2b)

4. d (para 3-3a,b)

5. d (para 3-4)

6. b (para 3-4a)

7. b,c,d,g (para 3-5a)

8. Addition of antioxidants
   Control of insects and rodents
   Prevention of rough handling and improper storage. (para 3-5b)

9. Addition of chemicals
   Refrigeration
   Freezing
   Canning
   Drying
   Irradiation (para 3-6)

10. a (para 3-7)

11. c (para 3-8a)

12. d (para 3-8b)

13. b (para 3-8d)

14. e (para 3-10)

15. c (para 3-11)

16. a (para 3-12)

17. a,c,e,f (para 3-14a)

18. b (para 3-14b)

19. Natural drying, including sun drying
Evaporation
Dehydration (para 3-15)

20. Temperature
Relative humidity
Air movement (paras 3-15 and 3-18)

21. a,c,d,f,g (para 3-15f)

22. e (para 3-15g)

23. a (para 3-16)

24. d (para 3-17b)

25. b (para 3-17b(2))

26. c (para 3-18)

27. a (para 3-18)

28. e (para 3-18a)

29. d (para 3-18b)

30. molding and rotting (para 3-18b)

31. wilting and dehydration (para 3-18b)

32. d (para 3-19)

33. a (para 3-19b)

34. c (para 3-19b)

35. b (para 3-20c)

36. d (para 3-20b)

37 gaseous; liquid; dry ice (para 3-21)

38. 2 percent (para 3-21b)

39. absorption of moisture and oxygen from the air (para 3-21c)

40. 2.5 to 5 million rad (para 3-22b)

41. a (para 3-23a)

42. c (para 3-23c)

43. d (para 3-23f)

44. c (para 3-23d,f)

45. a (para 3-24a)

46. e (para 3-24a)

47. b (para 3-24b)

48. a (para 3-25b(2))

49. Federal Register (para 3-27)

50. the organization that wants to use or market the additive (para 3-28)

51. b,c,f,h (para 3-29)

52. 1. Addition of borates in codfish and whole eggs to mask poor manufacturing or inadequate storage.
    2. Use of chrome yellow on coffee beans to make them appear to be of better quality.
    3. Use of copper on canned peas to make the peas appear younger in coloration.
    4. Addition of fluorine compounds in lieu of pasteurizing in beer and wine to stop fermentation.
    5. Addition of formaldehyde in milk to kill bacteria or in frozen eggs to conceal the odor of decomposition.
    6. Use of hydrogen peroxide as a preservative in cream and milk.
    7. Use of salicylates in shrimp sauce to delay decomposition.
    8. Use of sodium nitrate in fish fillets to prevent spoilage.
    9. Use of sulfites to redden stale meat. (para 3-30)

**End of Lesson 3**